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In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and x rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

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CONTENTS

Page

REPORTS

- Some Measurements on Radioactivity in Sweden
Caused by Nuclear Test Explosions..... 487

Attilio Magi, Jan Olof Snihs, and Gun Astri Swedjemark

- Environmental Survey of Uranium Tailings Pile,
Monument Valley, Ariz..... 511

Robert N. Snelling

- Results of a Study of Color Television Set Assembly
and Repair Workers X-Ray Safety..... 519

Stanley D. Savic

- Elevated Levels of Cesium-137 in Common Mushrooms
(*Agaricaceae*) with Possible Relationship to High Levels of
Cesium-137 in Whitetail Deer, 1968-1969..... 527

Wallace Johnson and Chester L. Nayfield

DATA

- SECTION I. MILK AND FOOD..... 533

- Milk Surveillance, June 1970..... 533

- Food and Diet Surveillance..... 543

- SECTION II. WATER..... 544

i

CONTENTS—continued

	Page
SECTION III. AIR AND DEPOSITION	545
Radioactivity in Airborne Particulates and Precipitation.....	545
1. Radiation Alert Network, June 1970, <i>NAPCA</i>	546
2. Canadian Air and Precipitation Monitoring Program, June 1970.....	549
3. Mexican Air Monitoring Program, January-June 1970.....	550
4. Pan American Air Sampling Program, June 1970, <i>PAHO</i> and <i>PHS</i>	552
5. Plutonium in Airborne Particulates, April-December 1969, <i>PHS</i>	552
Surface Air Sampling Program, 80th Meridian Network, January-December 1966.....	554
SECTION IV. OTHER DATA	563
Radionuclides in Alaskan Caribou and Reindeer, May-December 1969, <i>PHS</i>	563
Environmental Levels of Radioactivity at Atomic Energy Commission Installations.....	565
1. Knolls Atomic Power Laboratory, January-December 1968.....	565
2. Portsmouth Area Gaseous Diffusion Plant, July-December 1969.....	569
Reported Nuclear Detonations, September 1970.....	571
Errata.....	572
Synopses.....	iii
Guide for Authors.....	Inside back cover

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Reports

Some Measurements on Radioactivity in Sweden Caused by Nuclear Test Explosions

Attilio Magi, Jan Olof Snihs, and Gun Astri Swedjemark¹

Data on environmental radioactivity levels in Sweden during the period 1959-1968 are summarized. Emphasis is placed on gamma radiation from the ground and concentrations of cesium-137 and strontium-90 in some foodstuffs of special interest, such as dairy milk and reindeer meat. Various empirical correlations between the concentrations of radioactivity in milk and meat and those found in precipitation are discussed; such correlations may be used in planning environmental sampling programs. The radiation dose contribution to the population due to fallout is assessed and discussed.

As a result of the large number of above ground nuclear detonations conducted in 1958, 1961, and 1962, radioactive contamination of the environment increased considerably and the occurrence of cesium-137 and strontium-90 became significant from the point of view of radiation protection. The surveillance of these radionuclides was increased by the National Institute of Radiation Protection (formerly the Institute of Radiophysics) to include measurements of the radioactivity in the air, precipitation, and foodstuffs (especially milk) and whole-body measurements. In addition, a network of ionization chamber instruments for measurement of ground level gamma radiation was established. Twenty-four instruments were geographically distributed throughout the country (1). A whole-body counter was also acquired in order to measure the radioactivity in human beings (2). The device was a complement to the ionization chamber unit constructed by Sievert (3-5) for quantitative total determinations, and made qualitative radioactivity determinations possible.

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Fallout measurements were carried out in conjunction with other institutes. Measurements of radioactivity in meat were performed by the Royal Veterinary College; fish were analyzed by a department of the National Nature Conservancy Office; vegetables, by the Royal College of Agriculture, Ultuna; and air and precipitation, by the Research Institute for National Defense. The Institute of Radiation Protection was responsible for whole-body measurements, measurements of radioactivity in milk, and operation of the stations for measuring gamma radiation. Results from these measurements to the end of 1964 have been published earlier (6-13).

Although no nuclear tests series of the magnitude performed in 1961 and 1962 have been conducted above ground since 1962, the radioactive contamination of foodstuffs and radioactivity levels in human beings continued to increase until 1963-1964 but has since slowly decreased.

Fallout measurements are being continued at a reduced frequency to determine the decrease of radioactivity with time on the basis of meteorological, ecological, and biological factors, and to obtain an insight into the relationships which could arise between the radioactivity levels in different objects, places, and human beings. These data should facilitate the prediction of resulting contamination levels over longer periods in the event

of a future increase in fallout, and also indicate sampling and protection procedures. For example, it was found that reindeer meat can be a critical foodstuff in an unfavorable fallout situation because of the particular ecology found in northern Scandinavia and the considerable consumption of reindeer meat by the residents in these regions. Therefore, the contamination of reindeer meat and the high levels of radioactivity in Lapps have been the objects for specific investigations (14-16).

Partial results of the measurements and calculations made by the Institute of Radiation Protection since 1965 have been published at intervals in papers presented at congresses, in annual reports, in reports to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (17-46) and in reports for the Nordic collaboration on these questions (47). The reports have usually had the form of data summaries. This paper presents results and calculations of fallout measurements up to 1969.

Methods of measurements, calibrations, and inter-comparisons

Dairy milk in 3.8 liter Marinelli containers is analyzed with a 4-by 4-inch NaI (TI) crystal and a Nuclear Data multichannel pulse-height analyzer. The counting time was normally 40 minutes for which the minimum detectable activities (2σ background) are 0.09 g K/liter and 10 pCi ^{137}Cs /liter. Since the 6th of March 1967, the measuring time has been 80 minutes, which has given somewhat lower minimum detectable activities of 0.06 g K/liter and 7 pCi ^{137}Cs /liter. Usually, only the content of cesium-137 and potassium-40 is evaluated but during the routine standardized evaluation, attention is also given to the occurrence of other gamma-emitting nuclides, such as iodine-131 and barium-140.

Reindeer meat is measured as deep-frozen steak and corrections are made for fat and bone content. The samples (about 1.5 kg) are placed on a plate 30 cm above the NaI crystal.

Calibrations of radioactivity measurements in milk are performed with Marinelli containers containing ion exchange material with 41.3 nCi of cesium-137 (May 1962) or water with a potassium chloride equivalent of 131.0 g of potassium. The iodine-131 calibration is made in a corresponding manner. The reindeer meat measurements are indirectly calibrated by comparison with standard-

ized samples of milk powder containing a known quantity of cesium-137 determined from Marinelli container measurements.

The strontium analyses of dairy milk were conducted according to Bryant's method (48) during 1963 and 1964. From the spring of 1965, Butler's ion exchange method (49) has been used with the modification that the chemical yield of strontium is calculated from the calcium yield instead of using strontium-85 (HDEHP-method). Since 1967 the milk samples (each 350 ml) have been dried in air and ashed. The ash is dissolved in 1 N hydrochloric acid and yttrium-90 is extracted from the solution with HDEHP (50). The error in the counting is within ± 5 percent, the error in the chemical analysis is about ± 2 percent and the calibration error is less than 3 percent. Hence, the total error in the determinations of strontium is ± 7 percent (1 sigma error).

The beta radioactivity measurements were performed with an Intertechnique low energy beta-ray counter, type RA 12 (an anticoincidence-coupled flow counter with helium-isobutane as the counting gas). The background of the counter is 0.65 ± 0.05 cpm (maximum error). The efficiency of the counter measured on standard samples is 44.2 percent for yttrium-90 and 36.6 percent for strontium-90 in equilibrium with yttrium-90.

As a check on the reliability of the results, the analytical procedures were tested by the analysis of standard samples from the International Atomic Energy Agency (IAEA). These results have compared favorably with those from other laboratories in other countries. Figure 1 shows the result for the cesium-137 measurements.

Whole-body measurements were carried out in an "open-booth" type, whole-body counter (figure 2) from 1959 till 1965 (2). Since 1965, the measurements have been performed in a three-crystal counter placed in a specially built laboratory made of special concrete consisting of aggregate material and cement selected for their very low radioactivity (51-52). The measuring errors and the calibrations have been reported in detail (53). A review of the measuring errors in a single in vivo measurement for both the "open-booth" and the three-crystal counter is given in table 1. The errors in the calibration and the Compton part of the spectrum are calculated from measurements on phantoms. The error in

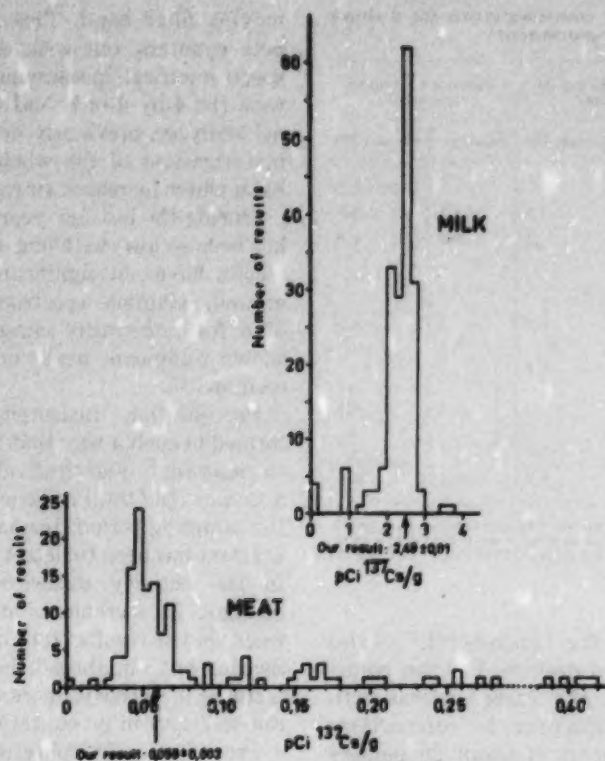


Figure 1. IAEA comparative measurements, 1966

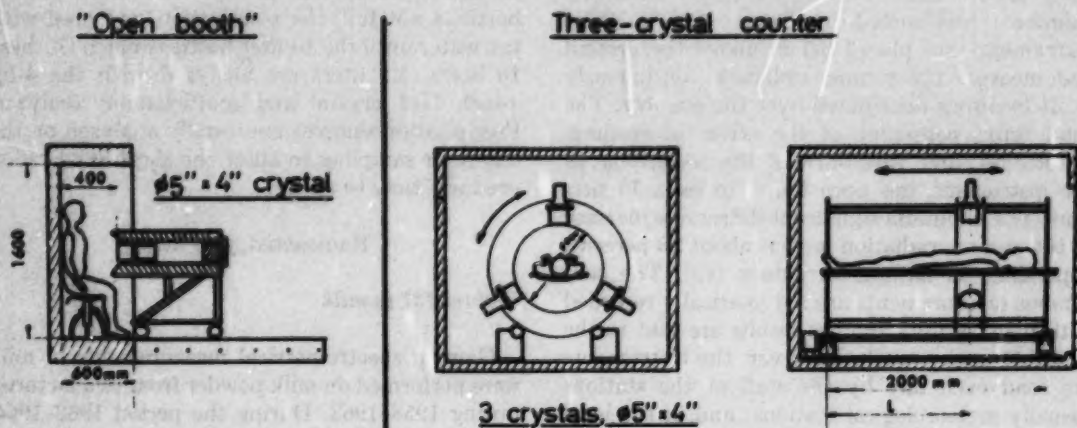


Figure 2. Open booth and three-crystal whole body counters

Table 1. Summary of the counting errors for a single in vivo measurement*

Type of error	"Open-booth" counter (percent)		Three crystal counter (percent)	
	Potassium	Cesium-137	Potassium	Cesium-137
Standard deviation due to counting (1 test).....	4.3	5.8	5.1	6.7
Calibration error.....	3.6	.5	3.0	4.0
The error in the Compton part of the spectrum due to potassium in the cesium interval	—	1.8	—	1.3
The error in reproducibility.....	4.0	4.0		
The error due to geometry originating from differences in body constitution.....	4.8	4.8	5.4	5.4
Total error (1 test)....	8.4	8.8	8.4	9.6

* The calculations have been made for 140 g potassium and 10 nCi cesium-137, assuming that the measuring time of the background is much greater than the measuring time of the subject (30 minutes). Bismuth-214 contamination was not considered.

the reproducibility for the "open-booth" device depends on variations in posture. For the potassium-40 measurements, the variation was estimated for a single measurement by comparisons of potassium measurements of about 20 persons in two observation series.

The measurement of the gamma radiation from the ground is made with high pressure ionization chambers constructed by Sievert (1, 54). The instruments are placed 2.5 m above the ground and measure the gamma radiation continuously at 24 locations distributed over the country. The total error, consisting of the errors of reading, calibration, and variations of the sensitivity in the instrument, has been found to be ± 10 percent. The minimum significant detectable increase in the gamma radiation level is about 20 percent, depending on natural variations (55). The continuous measurements are automatically recorded with point writers and the results are sent to the Institute once a week. However, the instruments are read each day by the staff at the stations (usually meteorological stations) and, if the level of the gamma radiation exceeds a predetermined level (about 60 $\mu\text{R/h}$), the Institute is contacted.

A continuous check on air radioactivity is kept at the Institute with an air monitor (type Frieseke & Hoepfner FH59A). It pumps air at 20 m³/h (4 m above ground level) through a continuously

moving filter band. This filter band passes two beta counters, one with optional delay. Gamma spectrometrical measurements can be performed with the 4-by 4-inch NaI crystal and multichannel analyzer, previously described, for qualitative investigations of the whole or parts of the filter band where increased air radioactivity is observed.

During the last few years, the air radioactivity has been so low (with one exception) that the beta results have not significantly varied from background. Gamma spectrometrical measurements of a few arbitrarily chosen filter samples have shown significant peaks only on beryllium-7 and cesium-137.

Precipitation measurements have been performed in such a way that it has not been possible to determine quantitatively and with any great accuracy, the total radioactivity deposited during the sampling period. Instead, the aim of the measurement has been to detect any significant increase in the activity deposited and its qualitative changes. Measurements are usually made once a week, but if results from other equipment within Sweden or from abroad should indicate a possible increase in activity, more frequent checks on the radioactivity in precipitation can be made.

Precipitation is collected immediately outside the Institute's building in a 10-liter plastic bottle placed at the bottom of a funnel formed by a 2 m² plastic cloth. If no precipitation falls, or if the bottle is not full, the plastic cloth is rinsed with tap water until the 10-liter bottle is filled. Of these 10 liters, 3.8 liters are analyzed with the 4-by 4-inch NaI crystal and multichannel analyzer. Precipitation samples are usually analyzed on the day after sampling to allow the short-lived radon products time to decay.

Radioactivity in food

Cesium-137 in milk

Gamma spectrometrical measurements of milk were performed on milk powder from two factories during 1958-1963. During the period 1962-1964, milk samples from 32 dairies were measured once a fortnight. During the winter and spring of 1965, a nationwide investigation of milk from all 292 dairies in Sweden was conducted. The intent was to determine the geographical distribution of cesium-137 over the country and to investigate the

7

possibilities of decreasing the number of sampling locations while increasing the sampling frequency and still maintaining the degree of preparedness.

Figure 3 (including Norway) (56) shows that the cesium-137 content varies regionally depending on the quantity of precipitation, among



Figure 3. The geographical distribution of the cesium-137 concentration in dairy milk, February-May 1965

other things (figure 4). The ratio between the cesium-137 concentration and the quantity of the precipitation during the preceding year is shown in figure 5. The ratios varied between 0.1 and 0.3 pCi/liter of milk per mm of precipitation/a for large agricultural regions, while for other regions the variation was greater (up to 0.7 pCi/liter of milk per mm of precipitation/a). The difference in the annual precipitation between these two types of regions is less than a factor of 1.5 and the difference in the ratios must principally be explained by differences in soil, fertilization, pasture, winter food, etc (17).



Figure 4. Total precipitation during 1964 (the isohyets for Norway are schematic)

Figure 6 shows the distribution of cesium-137 in crops and milk that can be expected from uptake from the soil as calculated by Fredriksson and Eriksson (57). The calculations are based on results of extensive tracer experiments with fission products and from investigations on the cesium-137 content in vegetation and milk. Figure 5 and figure 6 are based on different assumptions. The calculated values in figure 6 refer only to uptake from the soil. The observed ratios (milk concentration/precipitation) in figure 5 depend to a large extent on direct contamination of the fodder. Other influencing factors are imported fodder, the time distribution of the precipitation, etc.

On the basis of the results of the nationwide investigation, four large dairies (filled circles in figure 7) were chosen to provide the basis for the calculation of the nationwide average cesium concentration, and eight additional dairies were selected to check that the geographical distribution remained unchanged. In figure 8 the cesium concentration is shown as a percent of the nationwide average as a function of time. A seasonal variation



Figure 5. The geographical distribution of the ratio between the cesium-137 concentration in dairy milk during February-May 1965 and the total precipitation during 1964

can be established. The dairy N (Nässjö) increased in comparison to the nationwide average from the calculated 120 to 200 percent, an average increase during the whole period of 50 percent. The other dairies, with the exception of the small mountain dairies, have decreased in comparison to the nationwide average with an average decrease of 10-80 percent during the period, 1965-1968. The dairy N is included in the calculation of the nation-wide average. If dairy N is excluded, lower nationwide averages (4-37 percent lower) are found for 1965 to 1968. Negative deviations from

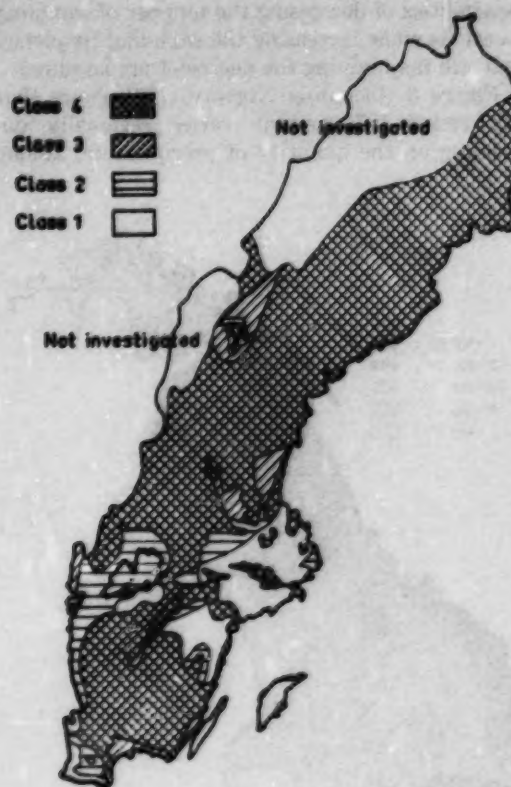


Figure 6. Anticipated content of cesium-137 in milk as a result of uptake from the soil (The land has been classified in four classes, 1-4, according to increased plant availability of the nuclides—after Fredriksson and Eriksson (57))

the nationwide averages are small while the positive ones are more pronounced. In the positive deviations, a trend to a continuous increase is found, while the negative ones show random variations. This can reflect differences in the soil, fertilization, etc, as the cause of the differences in the decrease of the cesium concentrations with time. The above mentioned facts and the poor agreement between cesium in milk and beef (page 496) suggest that the calculated nationwide averages are somewhat high. The results of the cesium-137 measurements are shown in figure 9, where the nationwide average, the dairy having the lowest content of cesium-137, and the one having the highest content have been indicated.

The analysis of milk also includes a determination of the natural potassium content. The average



Figure 7. Map of Sweden showing the sampling dairies and regions for meat sampling

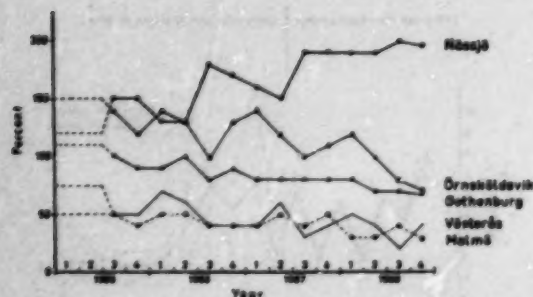


Figure 8. The cesium-137 content in dairy milk as a percentage of the nationwide average (Ornskoldsvik not included in average calculation)

for the samples taken during the summer months, June–October 1965, is 1.528 ± 0.003 g K/liter and during the winter months, November 1965–May 1966, 1.594 ± 0.003 g K/liter, where the

stated errors are the standard error of the mean. A significant decrease of the potassium content during the summer months is obvious. On the other hand, no geographical variation of the potassium content could be established.

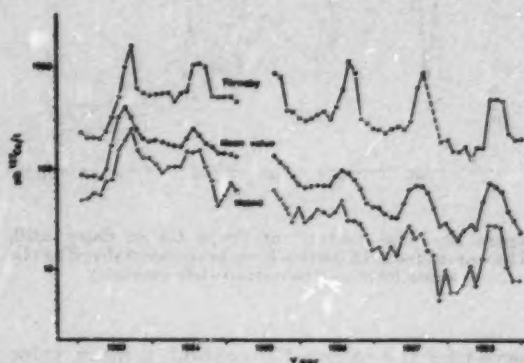


Figure 9. The cesium-137 content in dairy milk

Strontium-90 in milk:

Since July 1965, analyses of the strontium-90 content of one milk sample per month from each dairy are normally made. The average calcium content in milk is 1.189 ± 0.009 g Ca/liter (1-sigma error) calculated from data from the National Dairies Laboratory during September 1961-August 1962. No geographical variation nor any significant seasonal variation could be established.

The results of the strontium-90 measurements are shown in figure 10. The curves for each of the 12 dairies have been normalized so that the mean level during the period, July 1965–May 1968, coincide with the nationwide average during the same period. The remaining differences show deviations of the time patterns and the random variations. All the curves are contained in the area bounded by the grey curves around the heavy curve representing the nationwide average.

The nationwide average for the strontium to calcium ratio has not been weighted for the milk production. The small mountain dairies were included in the calculation of the arithmetical mean shown in figure 10. Excluding these dairies results in a mean value 84 percent of the mean shown in figure 10. If the same calculation is per-

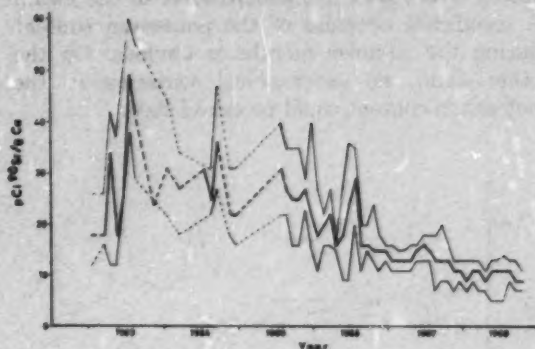


Figure 10. The content of $^{90}\text{Sr}/\text{g Ca}$ in dairy milk (The curves from 12 dairies have been normalized to the same level as the nationwide average)

formed for the cesium-137 content, a mean value 43 percent of the mean for all stations is determined. The geographical variation of the strontium to cesium ratio is consequently much smaller than that of the cesium content. The variation with time is also smaller for the strontium to calcium ratio than for the cesium content in milk. Figure 11 shows the strontium to calcium ratio and the cesium content in milk as a percentage of the level that occurred during the summer of 1963. The diagram indicates that during the winter of 1965, the two curves deviated so that the cesium content decreased faster than the strontium content. This would also cause a decrease of the cesium to strontium ratio.

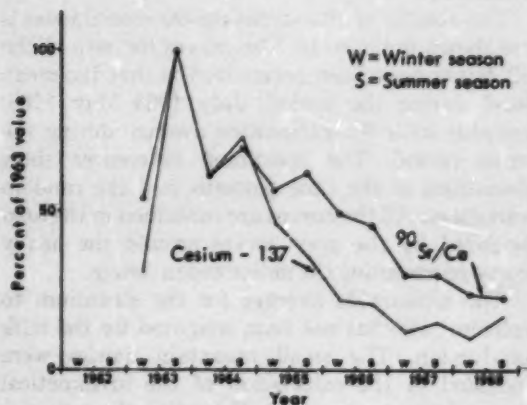


Figure 11. Cesium-137 and strontium-90 to calcium ratio as a percentage of the 1963 value

The ratio between cesium-137 and strontium-90 in milk

The cesium to strontium ratio has been calculated as the ratio between pCi cesium-137 per gram potassium and pCi strontium-90 per gram calcium. As already mentioned, the cesium to strontium ratio for milk varies geographically and with time. Figure 12 shows the time patterns for ten dairies from large agricultural regions for 1958-1968. The ten curves are normalized to the nationwide average. For 1959-1962, the curves were derived from samples of dried milk from two factories with the result that the ranges of values during that period are small. All the curves in figure 12 are contained in the bounded area around the heavy curve representing the nationwide average. Therefore, the bounded area represents both the random variation and the variations in the time patterns from dairy to dairy. The diagram shows that the time patterns for the "normal regions" in the country are quite similar. During years with fresh fallout, the summer values were higher than the winter values; this has also been found to be the case during 1967 and 1968. Peaks occurred for the nationwide average until the summer of 1964. Since then the averages have decreased until 1967 and 1968 when they were practically the same. For single dairies the ratios have increased by about 15 percent (four dairies) during the summer season.

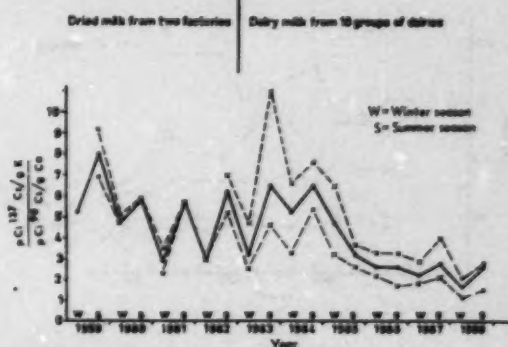


Figure 12. The ratios of $^{137}\text{Cs}/^{90}\text{Sr}$ (The curves from 10 groups of dairies have been normalized to the same level as the nationwide average)

The geographical variation of the cesium to strontium ratios, illustrated in figure 13, shows winter and summer averages for seven dairies from

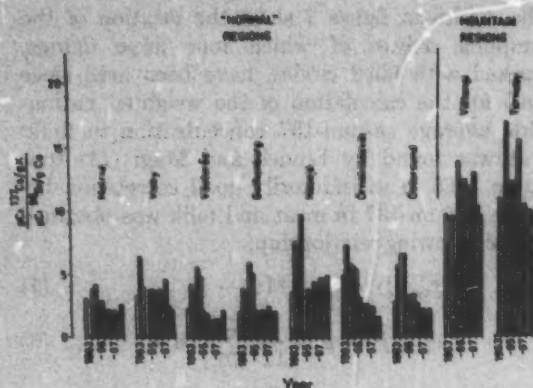


Figure 13. The $^{137}\text{Cs}/^{86}\text{Sr}$ ratios for eight of the sampling dairies (Dark columns represent summer seasons; white columns, winter seasons)

"normal regions" and for two dairies from mountain regions. The latter values are not only higher than the values from "normal regions" but the variations over a period of years as well as the seasonal variations are also different.

Correlations of milk levels to fallout levels

It has been shown (11, 13) that an equation of the following type satisfactorily gives the relationship between the mean annual cesium-137 concentration in Swedish milk and the cesium-137 deposited during 1962-1965, as reported by Lindblom and Bernström^a (58-61). The calculated value has been within 0.91 ± 0.13 times the observed values.

$$\bar{m}(i) = a F_1(i) + b F_1(i-1) \quad \dots (1)$$

where

$\bar{m}(i)$ = the mean cesium-137 concentration in milk for the year i (pCi/liter)

$F_1(i)$ = total annual cesium-137 deposition in the year i ($\text{mCi}/\text{km}^2 \cdot \text{year}$)

$F_1(i-1)$ = total annual cesium-137 deposition in the year $i-1$ ($\text{mCi}/\text{km}^2 \cdot \text{year}$)

a and b are constants.

However, during the years 1966 and 1969, the calculated value of cesium-137 in milk has been only one half to one third of the observed values.

^a B. Bernström, personal communication.

During these years, the cumulative deposition reached its maximum and it would seem that equation 1 gives a good correlation for relatively fresh fallout only.

This was also found to be the case for the following equation (62)

$$\bar{m}(i) = p_r F_1(i) + p_l F_1 + p_d F_d \quad \dots (2)$$

where

$\bar{m}(i)$ and $F_1(i)$ have the same meaning as above
 F_1 = deposition of cesium-137 in the second half of the previous year (mCi/km^2)

F_d = cumulative deposit of cesium-137 (mCi/km^2)

p_r , p_l and p_d are described as "rate", "lag-rate" and "soil" proportionality factors, respectively, expressed in pCi/liter per mCi/km^2 .

This relationship with $p_r = 3.0$, $p_l = 6.0$ and $p_d = 0.03$ (derived for the United Kingdom by Bartlett) gives levels which, for the period 1962-1966, are about 61 ± 10 percent of the observed Stockholm values for dairy milk. If data from the years 1967 and 1968 are included, the corresponding values are 52 ± 23 percent. The corresponding percentages for the nationwide averages are 39 ± 10 percent and 36 ± 18 percent, respectively. If Bartlett's constants are multiplied by 1.6, equation 2 results in levels close to the observed ones for Stockholm except those for 1966, 1967, and 1968, where the calculated levels were only $3/4$, $1/2$, and $3/4$, respectively, of the observed ones.

Data for strontium-90 in milk are not expected to satisfy an equation of the same type as equation 1 derived for cesium-137, since the value for the cumulative strontium-90 deposit has a substantial influence on the result. However, since a term for the cumulative deposition is included in equation 2, this equation may also apply for strontium-90 if proper values of the constants are chosen.

In the UNSCEAR report of 1966 (63) equation 3 was suggested for milk consumed by the world's population.

$$C(t) = p_d F_d(t) + p_r F_r(t) \quad \dots (3)$$

where

C = $^{86}\text{Sr}/\text{Ca}$ ratio in milk at time t

F_d = cumulative mean deposit of strontium-90 in soil in mCi/km²

F_t = mean annual fallout rate of strontium-90 in mCi/km² · year at time t

p_d and p_r = proportionality factors also referred to as "soil" and "rate" factors.

The strontium deposits were derived from cesium-137 measurements, assuming that the cesium-137/strontium-90 ratio in fallout is 1.7 for 1958-1961 and 1.5 for 1962-1966, as reported by UNSCEAR in 1962 and 1966 (64, 63). The strontium levels in milk calculated with $p_d = 0.3$ and $p_r = 0.8$ (the values suggested by UNSCEAR for milk consumed by the world's population) fall within the extreme limits of 91 ± 80 percent of the observed levels up to 1969.

For comparison, equation 2 was used with $p_r = 0.70$, $p_d = 1.13$ and $p_d = 0.11$ (derived for the United Kingdom by Bartlett (62)). The values fall within the extreme limits of 60 ± 17 percent of the observed levels up to 1969. If these constants are multiplied by 1.7, equation 2 results in levels in relatively good agreement with the observed ones, when it is considered that fallout data on strontium-90 are less complete than the available data for cesium-137 and that, in some circumstances, both data have been derived from assessments based on precipitation measurements when fallout data have been lacking.

Strontium-90 in milk from dairies with a small milk production in the mountain regions has been measured since 1963. Using equation 3 with $p_d = 0.3$ and $p_r = 0.8$ and on the assumption that the annual deposition is proportional to the annual precipitation, the calculated strontium levels in milk are 64 ± 23 percent (extreme limits) of the observed levels.

Correlations between cesium-137 levels in meat and milk

Monthly averages for the whole country of cesium-137 concentrations in beef and pork have been calculated from data reported by Åberg³ (65-66).

Meat samples are taken from eight regions A-H (figure 7). The nationwide average is calculated as an arithmetic mean of samples from these regions with corrections for missing values.

³ B. Åberg, personal communication.

The circles in figure 7 show the location of the sampling dairies of which four large dairies, marked with filled circles, have been used since 1965 for the calculation of the weighted nationwide average cesium-137 concentration in milk.

It was found by Lindell and Magi (13) that up to 1965, a satisfactorily good correlation between cesium-137 in meat and milk was obtained by the following relationship.

$$C_{\text{beef}}(j) = g_m \cdot M(j-1) \quad \dots (4)$$

$$C_{\text{pork}}(j) = g_p \cdot \frac{1}{12} \sum_{k=j-11}^{j-1} M(k) \quad \dots (5)$$

where

$c(j)$ = the calculated cesium-137 concentration in meat for month j .

$M(j-1)$ = the concentration of cesium-137 in milk in the preceding month $j-1$.

$$g_m = 4.34 \pm 0.17 \text{ pCi/kg per pCi/liter}$$

$$g_p = 4.64 \pm 0.17 \text{ pCi/kg per pCi/liter}$$

The measurements during 1966 showed that the relationship was still valid for beef (25) but not pork, for which the following relationship was derived based on data from August 1962 to March 1966.

$$C_{\text{pork}}(j) = AM + BM(j) + CM(j-1) \quad \dots (6)$$

where

$\bar{M}$ = the average cesium-137 concentration in milk during the grazing season, June-October of the preceding year, with a changed value for October, taken as the average between the two grazing seasons.

$$A = 1.8 \text{ pCi/kg per pCi/liter}$$

$$B = 1.0 \text{ pCi/kg per pCi/liter}$$

$$C = 0.5 \text{ pCi/kg per pCi/liter}$$

From the 1967 measurements, the relationship for beef (equation 4) is found to be valid up to 1969 with the exception of the third quarters of 1967 and 1968, when the calculated beef activity is about three times the observed values (figure 14).

A comparison between milk and beef radioactivity from the same regions showed that the relationships were acceptable for those regions where the dairies are representative. Hence, the less satis-



Figure 14. Nationwide averages of the observed cesium-137 concentrations in beef and calculated beef concentrations according to equation 4

factory agreement for the past years between the observed and calculated cesium-137 concentration in beef for the whole country may depend on the actual differences in the methods of calculating the nation-wide averages for beef and milk.

The measurements in pork for 1967 and 1968 were found to give a poorer correlation than earlier measurements when calculated by equation 6. From figure 15 it is seen that the calculated nationwide averages for the cesium-137 content in pork are about twice the observed values during 1967 and 1968.

Since the correlation between pork and milk radioactivities is obviously not as direct as that between beef and milk activities, comparison of the calculated and observed cesium-137 concentrations in pork for each region is likely to give more ambiguous results than a similar comparison for beef. However, an investigation of the five regions where sampling dairies are situated showed that the averages calculated for 5 years were between the extreme limits of 75 and 165 percent of the observed values.

Cesium-137 in reindeer meat

Since the autumn of 1961, samples of reindeer meat have been collected twice a year and measured at the Institute. As a rule, samples have been requested from 13 regions (A-M) shown in figure 16, although it has only been possible to obtain samples from both winter and autumn slaughters from only one of these regions during the whole period. Nowadays, since the reindeer slaughters usually take place in the autumn, these past few years it has been difficult to cover identical regions during both autumn and winter. Since the winter slaughter of 1966/1967, the sampling program has been decreased to four regions A, E, F, and I.

The values obtained since the sampling program was decreased to four regions have been found to agree to within ± 10 percent with values obtained from the earlier, more comprehensive program, when samples from at least three of the four regions were received and a correction for the selection of regions was made. The variations of the mean (corrected for the actual selection of

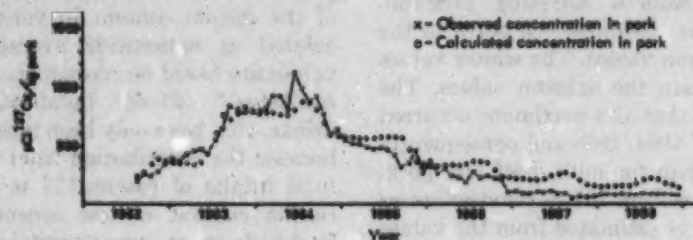


Figure 15. Nationwide averages of the observed cesium-137 concentrations in pork and pork concentrations calculated according to equation 6

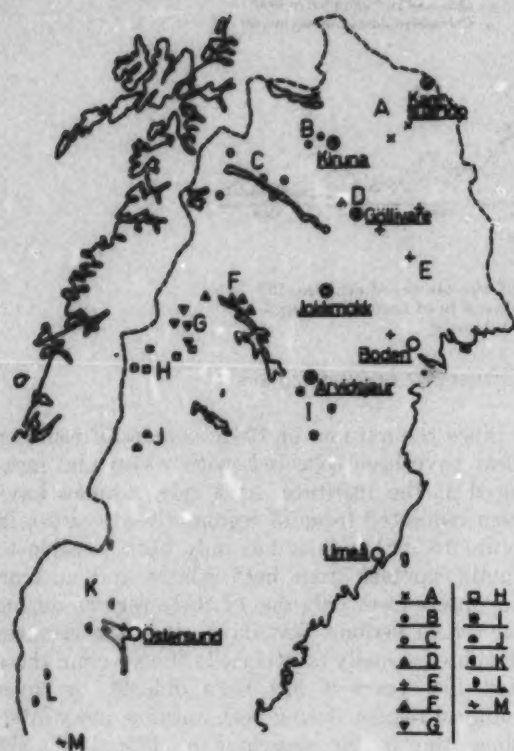


Figure 16. Regions in Sweden sampled for reindeer meat

regions each time) are shown in figure 17, where the highest and the lowest values are also indicated. The lowest values from 1966/1967 and later have been excluded because neither of the regions with the lowest cesium contents (H and J) are included in the reduced sampling program. The errors indicated for 1967 and 1968, refer to the experimentally determined deviations resulting from the reduced sampling program. A constant feature is the difference between the winter and the autumn values. The winter values have been higher than the autumn values. The diagram also shows that the maximum occurred during the winter of 1964/1965 and consequently considerably later than for milk, beef and pork.

The "half-life" of cesium-137 in reindeer seems to be about 4 years, as estimated from the values for samples from the winter slaughters. The values from autumn slaughters have increased since 1966. It is not possible to exclude the possibility that this is a result of the reduced sampling

program, despite the correction for the selection of regions on each occasion. Hence, it has not been possible to estimate the "half-life" for values from the autumn slaughters.

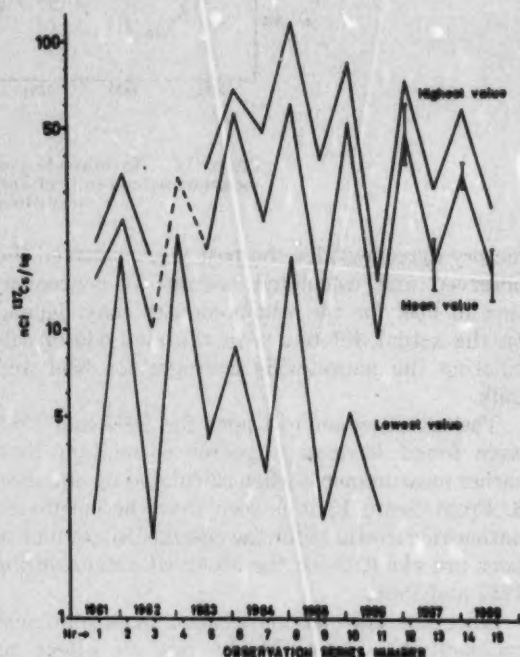


Figure 17. Cesium-137 content in deep-frozen reindeer meat (Errors indicated are the maximum errors given by reduction in sampling program)

Cesium-137 in the diet

The total intake of cesium-137 in the diet can be estimated from the measured cesium-137 content in the most common foodstuffs and their proportion in a normal diet. Table 2 is a summary of the cesium content in various foodstuffs calculated as nationwide averages. Some of the values are based on measurements made by other institutes^{1,4,5} (65-66). Potatoes, fruit, vegetables, drinks, etc., have only been measured sporadically because the contribution from these items to the total intake of cesium-137 is small due to low cesium content or low consumption. Imported foodstuffs cause some uncertainties in the estimation of the averages.

¹ L. Hannerz, personal communication.

⁴ A. Eriksson, personal communication.

Table 2. Summary of cesium-137 content in foodstuffs during 1962-1968

Date	Nationwide averages (pCi/kg)						
	Milk	Beef ^a	Pork ^a	Grain ^b	Fish from salt waters ^c	Fish from oligotrophic lakes ^c	Reindeer meat
1962.....	120	380	190	305	100	2,000	17,000
1963.....	185	750	580	765	100	2,000	17,000
1964.....	180	760	845	310	100	5,000	39,000
1965.....	125	470	445	125	100	5,000	20,000
1966.....	70	230	235	65	100	5,000	14,000
1967.....	50	105	85	40	100	4,500	20,000
1968.....	40	95	85	40	100	4,000	17,000

^a Data from the Royal Veterinary College.

^b Data from the Royal Agricultural College.

^c Data from a department of the National Nature Conservancy Office.

A summary of the annual cesium-137 intake as nationwide averages is given in table 3 for 1962-1968. These values were calculated on the basis of the values in table 2 and a normal composition of the diet (67). No direct measurements on diet samples have been made. The information regarding the composition of the diet is valid for 1960 and possible changes of dietary habits have not been considered. The foodstuffs not included in the table were estimated to make up about 10 percent of the total intake of cesium-137 excluding the contribution from reindeer meat. This estimation is based on both sporadic Swedish measurements and on measurements on Danish foodstuffs (68-71). The latter show that root vegetables, fruit, eggs, coffee, and tea amount to 6-19 percent, with a mean of about 10 percent of the annual cesium-137 intake during 1962-1967. We can expect that the percentage part denoted "others" varies with time, but because it contains several components, some of them im-

ported, the variation of the individual foodstuffs compensate each other to a large extent.

Because some foodstuffs (for example, milk) to a large extent are consumed in the regions where produced, variations of the cesium-137 intake are found for different parts of the country. For example, in the Stockholm area, the cesium intake is about 60 percent of the intake estimated as the nationwide average.

The cesium content of various foodstuffs differs both with regard to the absolute level and variation with time. Foodstuffs with high cesium-137 content do not usually belong to the normal diet. An exception is reindeer meat, which constitutes a considerable part of the diet of the Lapps. Of great importance are the common foodstuffs—milk, beef, pork, and grain. They have a lower cesium content but together have contributed more than 70 percent of the total cesium-137 intake during 1963-1965, the years with the highest total cesium-137 intakes.

Table 3. Summary of annual cesium-137 diet intake from various foodstuffs

Year	Nationwide averages (nCi/person)						
	Dairy products	Meat	Grain ^b	Lake fish from oligotrophic lakes	Salt water fish	Reindeer meat	Total intake in- cluding "others" ^d
Average annual consumption per person.....	Milk 175 kg ^a Cheese 18 kg ^a	48 kg ^a	88 kg ^a	Fish consumption 17.6 kg ^a		0.3 kg	
1962.....	* 23.0 (41)	18.2 (33)	0	2.5 (4)	1.6 (3)	5.1 (9)	56
1963.....	35.1 (37)	28.8 (30)	13.4 (14)	2.5 (3)	1.6 (2)	5.1 (5)	95
1964.....	33.6 (25)	38.4 (28)	33.7 (25)	6.3 (5)	1.6 (1)	11.7 (9)	137
1965.....	23.7 (30)	22.1 (28)	13.6 (17)	6.3 (8)	1.6 (2)	6.0 (7)	80
1966.....	13.4 (29)	11.0 (24)	5.6 (12)	6.3 (14)	1.6 (3)	4.2 (9)	46
1967.....	9.7 (30)	4.3 (13)	2.8 (9)	5.6 (17)	1.6 (5)	6.0 (18)	32
1968.....	7.4 (29)	4.3 (17)	1.8 (7)	3.6 (15)	1.6 (6)	5.1 (20)	26

* Data from the National Swedish Institute of Public Health.

^b Estimated: 50 percent in flour and consumption of the harvest of the preceding year.

^c Estimated: divided into lake fish 2.5 kg and salt water fish 15.1 kg. About half of the lake fish is estimated to be from oligotrophic lakes.

^d Estimated: "others" is 10 percent of the total intake excluding reindeer meat.

* Within parenthesis: percentage of total intake of cesium-137.

As shown in table 3, the relative contribution of the various foodstuffs to the total intake varies with time. As the cesium-137 content of usual foodstuffs has decreased, the relative contribution from other foodstuffs has risen. The relative increase of the contribution from fish and reindeer meat depends on the fact that the cesium content in these foodstuffs does not decrease with the same time pattern as milk, beef, pork, and grain.

From 1964 to 1968, the total intake of cesium-137 has decreased by about 80 percent.

Cesium-137 body burden

Measurements of the cesium-137 activity in human beings have been made four or five times a year on a group of about 20 persons employed at the Institute. The age of the members of the group is between 20 and 60 years. The calculation of the average was corrected for the differences occurring in the composition of the group. As seen from figure 18, the cesium-137 activities were calculated per gram potassium. In this way a quantity less dependent on body weight and sex is obtained. Its variation can thus be studied more easily and univocally. Table 4 illustrates the differences between cesium-137 levels in males and females. As is shown in table 4 and figure 18, the body burden reached a maximum in 1964 and has since decreased with a "half-life" of about 2 years. From measurements in Denmark and the United States of America, the "half-life" is reported to be $1\frac{1}{2}$ years (71, 72). The difference in the "half-lives," as in absolute activity

Table 4. Cesium-137 in humans*

Date	Number of persons			Cesium-137 ^b (nCi/person)		
	Total	Female	Male	Mean	Female	Male
May 1966.....	23	10	13	19.2	11.5	25.0
October 1966.....	23	9	14	15.9	11.1	18.9
April 1967.....	22	9	13	13.3	6.9	17.7
June 1967.....	19	8	11	14.2	6.3	20.0
October 1967.....	21	8	13	17.1	7.7	22.5
February 1968.....	22	9	13	14.1	5.6	19.9
May 1968.....	17	6	11	12.2	3.9	16.7
September 1968.....	15	6	9	11.9	4.0	17.2
November 1968.....	16	5	11	10.1	3.5	13.1

* Measurements made on a group of about 20 persons employed at the Institute.

^b Corrected only for radon-222.

levels, reflects the variation in the cesium-137 content of the foodstuffs and in the composition of the diet in various countries. The effect of an occasional change of the composition of the diet is illustrated by the October 1967 value in figure 18. A large number of the members of the group ate reindeer meat twice during September and October with a significant increase in the cesium body burden as a consequence.

Because the measured group consisted of only 20 persons, not randomly chosen, it cannot be considered as representative for Stockholm and still less representative for the whole country. Using the estimated cesium-137 content in the diet given in the preceding section, body burdens can be estimated and compared with the observed ones. The result is shown in figure 19. The calculations were based on the cesium-137 content in the Stockholm diet and an effective half-life of 100 days. Despite a rather rough method of calculation (constant intakes per year)

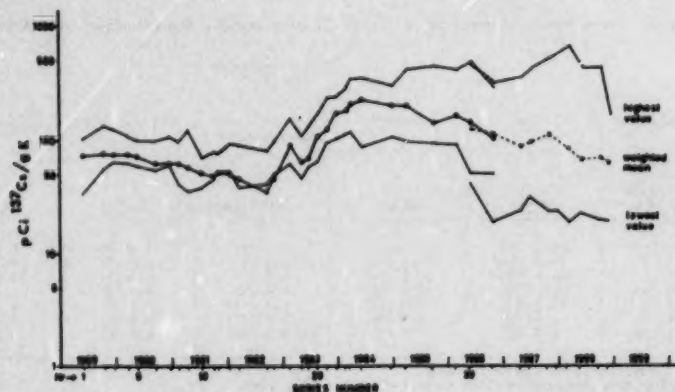


Figure 18. Cesium-137 body burdens of a group of Stockholm residents

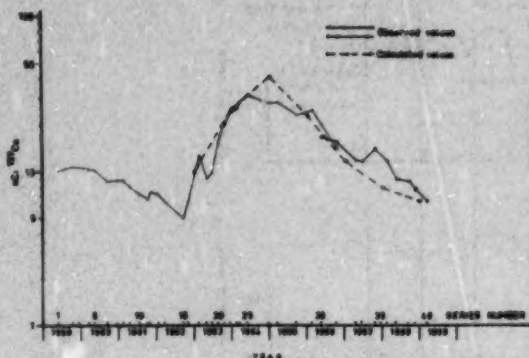


Figure 19. Observed body burdens compared with calculated body burdens

and the uncertainty in the representativeness of the group for Stockholm, a comparatively good agreement between the calculated and the observed body burden was obtained.

Gamma radiation at ground level

Measurements of the gamma radiation at ground level have been performed continuously since 1960 (7, 12, 19, 24, 33) at 24 places in Sweden, distributed over the country as indicated on the map in figure 20. Since the beginning of 1967, only the records from the five stations named on the map have been used for evaluating the exposure. Records from the other stations were examined only as a check.

The variation in the exposure in $\mu\text{R/h}$ during the period 1960-1968 is shown in figure 21 for one station (Erken) located in central Sweden and one (Torslanda) in southern Sweden. The broken lines indicate the level found during the summer months of 1960 and 1961 before the large nuclear weapon tests of 1961 and 1962. The dot-dashed lines indicate the contribution from cosmic radiation. To illustrate the absorption in the snow cover, the monthly averages of the snow cover have been indicated at the bottom of each diagram. The values regarding the snow cover are based on data issued by the Swedish Meteorological and Hydrological Institute.

From figure 21 it is seen that the depth of the snow cover has a striking influence on the gamma-radiation level. Other variations due to natural factors depend on the freezing of the ground,

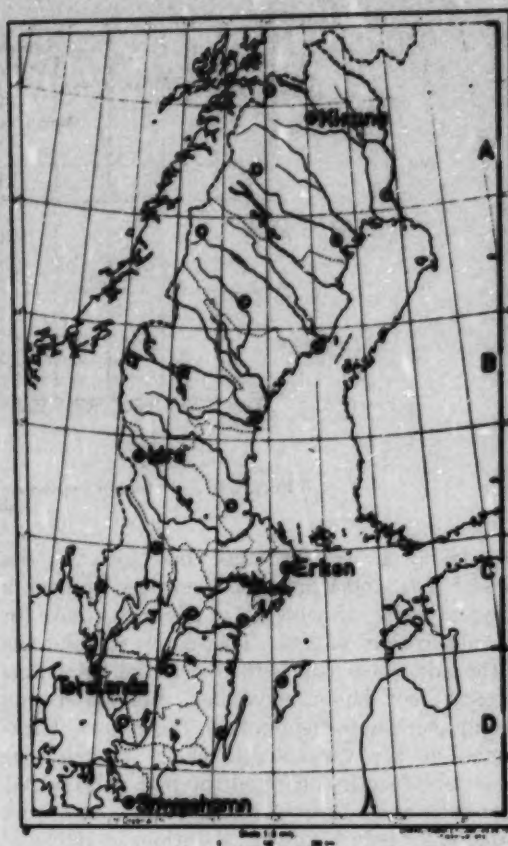


Figure 20. Stations for recording gamma radiation from the ground

variations in air pressure, precipitation etc. Precipitation can give rise to short increases up to 20 percent (55). Variations due to air pressure are of the same magnitude but of longer duration. The natural gamma radiation at ground level, based on values from the summer seasons, varies for the various stations between 62 and 96 mR/a of which about 30 mR/a is the contribution from cosmic radiation. The differences in these background levels depend on differences in the radioactivity in the ground under the ion chamber. Particularly in the north of the country, there is a seasonal variation of the exposure above the ground, depending to a large extent on the absorption in the snow. During 1960-1961, measurements of the natural radiation were made and corresponding variations were found. The absorption of radiation by the snow cover depends

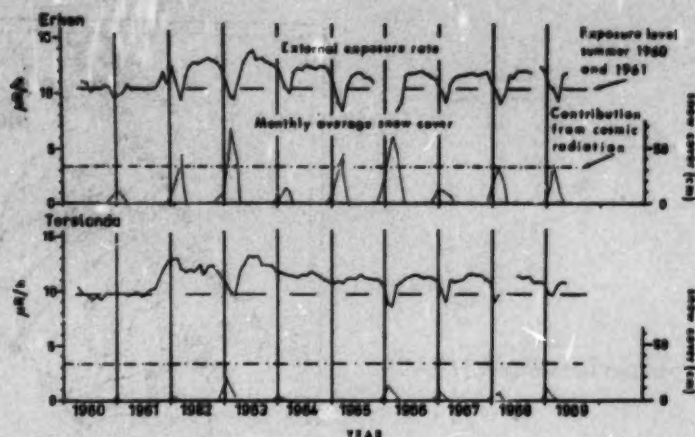


Figure 21. External exposure rates and monthly averages of the snow cover

not only on its thickness but also on its density (73), and it has not been possible from a practical point of view to make corrections for the absorption effects. Therefore, calculations of the additional exposure due to fallout (table 5) have been based on values obtained during the summer (June–September). For natural background at the various measuring stations, the values obtained in 1960 and the first half of 1961 have been used. Natural background values were obtained for only 11 of the 24 stations in 1960 and 1961.

As a comparison to annual values calculated from data obtained during the summer months, the exposures due to fallout based on annual values

have been calculated and are given in brackets in table 5. These values are influenced not only by variations in the exposure due to fallout but also by variations in the snow cover from year to year, mostly for the stations in central Sweden. This is shown particularly for station C3. In 1960–1961, this station had exceptionally little snow. Therefore, the background value used will be overestimated during snow-rich years, such as 1965 and 1966, and the net exposure per year will be too low.

The maximum deviations between the additional exposure calculated on values from four stations compared with values from 11 stations were found to be 0 to +2 mR/a. The four sta-

Table 5. Annual exposures due to fallout from gamma radiation at ground level^a

Station	Latitude	Background radiation ^b (mR/a)	Additional exposure due to fallout (mR/a)							
			1961	1962	1963	1964	1965	1966	1967	1968
B6 Idre.....	62°	78 (70)		11 (10)	25 (10)	16 (17)	13 (12)	10 (7)	11 (7)	12 (8)
C3 Erken.....	60°	91 (91)		22 (16)	26 (15)	16 (13)	10 (2)	13 (1)	11 (7)	13 (8)
D2 Torslanda.....	58°	85 (85)		21 (21)	29 (19)	16 (15)	14 (11)	14 (9)	12 (10)	14 (8)
D6 Smygehhamn.....	55°	82 (83)		11 (12)	17 (13)	9 (7)	7 (6)	6 (4)	6 (4)	7 (5)
Average of 4 stations.....			(3)	16 (15)	24 (17)	14 (13)	11 (8)	11 (5)	10 (7)	11 (7)
Average of 11 stations ^c			(5)	17 (16)	24 (19)	14 (13)	12 (9)	13 (6)		

^a Calculated on the basis of values obtained during the period June–September. Values in parenthesis represent average exposures based on values obtained during the whole year (including absorption in the snow).

^b Total before 1961, including the contribution from cosmic radiation.

^c See text.

tions used for calculations since the beginning of 1967 can therefore, be considered as fairly representative.

The maximum additional exposure due to fall-out occurred during 1963 and has been followed by a decrease with an approximative half-life of 2 years. During the past 4 years, the values have been fairly unchanged.

Fractionation phenomena from leakage from underground nuclear test

On the 25th and 26th of December 1966, a temporary increase of fallout was observed. The event has been reported earlier (31) and similar observations were made at other measuring stations in Sweden (74) and in Finland (75). The absolute activities in Sweden appeared to have no significance from the dose point of view, but the composition of the radioactivity was interesting.

About 9 p.m. (central-European time) on December 25, 1966, a significant increase in air radioactivity was measured by the continuously running air monitor. It decreased to normal values about 25 hours later. According to the results from the air monitor, the air radioactivity was 50 pCi-h/m³, i.e. the average concentration was 2 pCi/m³ with a maximum of about 2.5 pCi/m³. The part of the air filter corresponding to the time in question was measured by gamma spectrometric methods and the spectrum showed marked peaks which, by their energy and half-life were identified as barium-lanthanum-140. No other radioactivity could be found.

Radioactivity in precipitation from the period December 24 to 27, 1966, was measured by gamma spectrometric methods and two close-lying peaks were found at energies corresponding to cesium-137 and zirconium-niobium-95, and another at the energy, 480 keV (beryllium-7). There was no indication of any peaks corresponding to barium-lanthanum-140 (figure 22). There was no precipitation on the 26th of December, when, according to the air monitor, the radioactivity concentration in the air was at a maximum. The activity which fell as dry deposition the same day was evidently not enough to be measurable in the precipitation sample.

Several measurements were made on the precipitation samples at later times. Determination

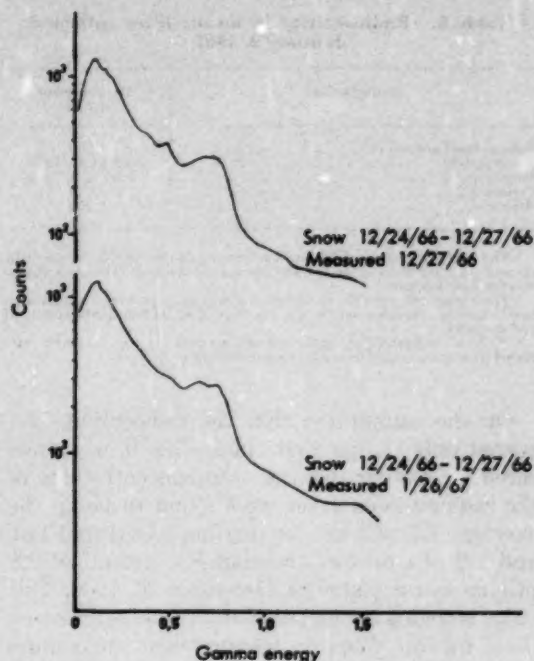


Figure 22. Radioactivity in precipitation

of the half-life resulted in $T_{1/2} = 81$ days for the peak around 750 keV (the measurements were made for about 2.5 months). The energy and the half-life indicated zirconium-niobium-95 with an effective age of some months. The other peak (within 600-700 keV) showed no significant decay during the same measuring period. The energy and the long half-life indicated the presence of cesium-137.

The section of the air filter corresponding to the time of interest was radiochemically analyzed for strontium. The analysis and the beta measurement were made according to the method used for foodstuff (page 488). The content of strontium-90 and strontium-89 was determined; the first was identified by precipitation of yttrium-90; the latter, by determination of the half-life.

The results of the measurements are seen in table 6. The activity was calculated to the 2d of January 1967 (see below for comparison with the Japanese measurements). The amount of barium-lanthanum-140 was estimated from the gamma spectrometric measurements. The percentage contribution of the different components to the total activity is seen in table 7.

Table 6. Radioactivity in an air filter collected January 2, 1967

Radionuclide	Measurement (pCi)
Barium-lanthanum-140	• 380
Strontium-89	370 ± 30 (1σ)
Strontium-90	2.30 ± 0.3 (1σ)
Cesium-137	• 10
Others	• 100

• The activity values of barium-lanthanum-140 cannot be given with greater accuracy than ± 30 percent because of the lack of direct calibration for these nuclides.

• The maximum activity of cesium-137 was estimated from the gamma spectrometric measurement on the air filter after barium-lanthanum-140 had decayed.

• "Others" indicates the maximum gamma activity which can be estimated from gamma spectrometric measurements on air filter.

On the assumption that the radioactivity occurred only during that time when it was measured by the air monitor, the concentrations of the radionuclides in air were found to be on the average 1.6 pCi/m³ for barium-lanthanum-140, and 1.2 pCi/m³ for strontium-89; a total of 2.8 pCi/m³ as calculated to December 26, 1966. This value is somewhat higher than the one determined from the air monitor measurement (maximum value was 2.5 pCi/m³ with the calibration date given.) The difference in the results can probably be explained by the fact that the efficiency of measurement is overestimated. The efficiency of filtration, (said to be 70 percent) has no influence on this comparison, as it is included in both values. After a plausible correction of the values, the comparison shows that there is no room for any "other" beta radioactivity of importance, which agrees with the results in table 7.

Table 7. The percentage contribution to the total radioactivity

Radionuclide	Percentage
Barium-lanthanum-140	61
Strontium-89	43
Strontium-90	• 1
Cesium-137	1.2
Others	12

• The strontium-90 value for a filter which represents the time before the time of interest is subtracted from the strontium-90 value.

The above mentioned observations are worthy of attention not because of the quantitative results which are quite negligible from the point of view of radiation protection, but because of the radioactive elements which were found in the fallout and the relationship between them. The

last above-ground nuclear test which could influence the measurements of fallout on the 25th-27th of December 1966 was the Chinese nuclear test of October 27, 1966. However, the time difference (60 days) makes it improbable to find such pronounced barium-lanthanum-140 peaks in the spectrum of an air sample without any other significant peaks. On the contrary, there are reasons to believe that the air radioactivity comes from a leakage from an underground nuclear test explosion. On January 30, 1965, Koyama et al. (76) measured fallout in Japan, which they could prove to have been caused by a leak from a Russian underground nuclear test explosion on the 15th of January the same year. They found the radionuclide composition in precipitation that is presented in table 8. Their values are compared with the composition that would be expected 15 days after fission of uranium-235.

Table 8. Percentage contribution to the total radioactivity, Japan, January 30, 1965

Radionuclides	Measured	Expected
Strontium-89	60	4
Strontium-90	.6	.03
Barium-lanthanum-140	34	26
Cesium-137	.2	.03
Others	5	70

The elements and their relative amounts which are measurable after a leakage are determined partly on the basis of the properties of their radioactive precursors. This means that during the leakage, there is an enrichment of those elements whose precursor is a gas (krypton, xenon) with an appropriately long half-life. For this reason, strontium-89, barium-140, and lanthanum-140 appear in the relatively high portions shown in table 8. Iodine-131, which normally dominates fresh fallout after nuclear test explosions above ground, was not reported in the Japanese observations. On the other hand, tellurium-iodine-132 could be found. This is due partly to the fact that during a given time there is a greater production of tellurium-132 by decay of the short-lived 132-isobars in the decay chain, Sn-Sb-Te-I than the production of tellurium-131 from the decay of 131-isobars.

Other factors will also influence the immediate fractionation and the fractionation which is observed at a long distance from the leakage (for

instance, meteorological conditions). It is thus difficult to predict the composition of the activity with any great accuracy or to be able to draw any conclusions concerning the source of the activity from the observed composition of the fallout activity. If one compares the fallout observed on the air filter on the 25th-27th of December 1966 with the fallout from the leakage observed abroad, there is obviously a similarity in the fractionation, indicating that the fallout observed in December 1966 was caused by a leakage from an underground nuclear test. Such a test was made on December 18, 1966, in the Semipalatinsk area in central Asia. At that time, the meteorological conditions were such that it is plausible that the observed increase of the fallout level in Sweden could have been caused by leakage from that underground test.

The radioactivity, observed in precipitation during the period December 24-27, 1966 (no precipitation on the 26th of December), did not have the same composition of gamma-ray emitters, as the air radioactivity. The presence of zirconium-niobium-95 and the absence of barium-lanthanum-140 is fairly characteristic of fallout caused by a nuclear test above ground (the latest before the time of measurement was the test on October 27, 1966) and does not indicate fallout from a leakage.

Discussion

Extensive fallout measurements were begun before the large nuclear weapon tests in 1961 and 1962 and have continued since then for a period of nearly 10 years. It has been possible to follow the radioactive contamination of the environment in all its phases, from the large and rapid increase during 1962-1963, its maximum during 1963-1964, and its slow decrease to levels, which today in some parts of the environment, are hardly measurable. As mentioned in the introduction, the purpose of the measurements was to obtain a nationwide picture of the magnitude and the variation of the radioactive contamination in different parts of the country and during different periods of time. The purpose was also to find the relationships between the radioactivity in different parts of the environment and in the human being, in order to gain a practical basis for action in possible future increases in fallout activity. Because of the purpose and the plan of

the measurements, it was outside the scope of the investigations to examine in detail the reasons for local differences and time differences of the contamination of the environment. The correlations presented are empirical and the magnitude and variation of the contamination of the environment has been explained against the background of known ecological, meteorological, or other factors, or they have been presented just as facts. Therefore, many of the data which have been presented will call for further investigation.

Our investigations concern predominantly cesium-137. The occurrence of iodine-131 during 1961 and 1962 has been presented earlier by Lindell (13). In the period after 1963, there has been no measurable contamination by iodine-131. The strontium-90 content in milk has also been routinely examined. Other nuclides in fallout, such as zirconium-niobium-95, have not appeared in measurements on foodstuffs but have had an influence on the amount of external radiation from the ground.

The radioactive contamination of the environment depends primarily on the available activity on the ground and in the air. As found by measurements on air and precipitation³ (58-61) the fallout rate of cesium-137 and strontium-90 reached its maximum in 1963 and the accumulated fallout reached its equilibrium value in 1966-1967. The time variation of the activity in different diets and in the human body reflects the influence of those factors which determine the further transport of the radioactivity in the environment such as ecological and biological factors, storage, etc.

The most direct connection between the radioactivity (per unit of area and time or accumulated) and the contamination of the environment should be found in the direct measurements of radiation above the ground. However, interpretation of these measurements, as some function of the fallout activity, will be complicated by seasonal screening effects, the penetration of radioactivity into the ground and radiation from airborne activity. The results are unambiguous as a measure of the exposure above the ground. The gamma radiation is primarily due to cesium-137, with the exception of the time immediately after a nuclear test when short-lived radioactive nuclides contribute to the exposure. The maximum during 1963 corresponds to a maximum in the airborne

radioactivity and the fallout rate. The subsequent slow decrease of the exposure rate ceased in 1965 and since then has been fairly constant. In contrast to this, the airborne radioactivity and the fallout rate have continuously decreased except during the past 2 years, when new contributions of fresh fallout have occurred.

As discussed in the gamma radiation at ground level section, there are difficulties from a practical point of view in making corrections for the absorption of gamma radiation in the snow. The best values of the yearly exposure of all stations in central and northern Sweden are obtained if the averages based on values from the summer season (table 5) are multiplied by 0.8, provided the accumulated activity does not change considerably during the year and the winter is not unusually snow rich. For the stations in southern Sweden, the corresponding factor is close to one. Without any detailed knowledge of the snow conditions or specification of the measuring place, the uncertainty will thus be about 25 percent.

The variation of the cesium-137 content in milk has largely followed the same time pattern as the variation of the fallout rate with significant peaks during the spring and summer months, indicating that it is mainly the fresh fallout which will be found in milk. The connection is complicated by the fact that cows do not graze outdoors until spring. This fact alone would indicate an increase in the radioactivity in milk, even under conditions of equal deposition rate during the year. It has also been possible to show a connection between the yearly fallout and the cesium-137 content of milk with good agreement between the calculated and the observed levels of cesium-137, up to 1966. Thereafter, the observed values have been higher than the calculated levels. The cesium-137 content of milk has been fairly constant since 1966, perhaps due to the relatively greater importance of the accumulated fallout. In this case, the influence of different soils, fertilizer, etc., in different agricultural areas should be more noticeable.

As seen in figure 8, the cesium-137 content in milk from different dairies has also changed differently in comparison with the calculated nationwide average. This is also seen in figure 9, showing an increasing difference with time between the cesium-137 content in milk from Tarna-

by and that from Malmö, representing two different agricultural regions.

The radiation exposure to man caused by the radioactive fallout consists partly of external exposure primarily from radioactivity on the ground, and partly of internal exposure from the accumulated radioactivity in the body. Large local variations may occur as far as the internal exposure is concerned because of different diets. For instance, the Lapps in the north of Sweden have a higher cesium-137 body burden than the nationwide average because of their higher consumption of reindeer meat. However, Gustafsson and Liden (16) found that the increase of the total exposure caused by the consumption of reindeer meat does not fall beyond the limits of variations in natural radiation exposure to other persons. Those whose consumption of milk and meat is low, constitute a group with low cesium-137 body burdens. As seen from table 3, the difference in the percentage of cesium-137 intake via different foods was smaller during the past years. Earlier, fish and reindeer meat contributed to the nationwide average by less than 10 percent of the total intake of cesium-137. In 1967 and 1968, these foods together contributed almost 40 percent of the cesium-137 body burden since the rate of decrease of cesium-137 in these foods is lower than in other foods. This implies that the difference between extreme values of the body burden should increase with time, which is also seen in figure 18. In this case, the maximum values represent a man whose consumption of reindeer meat was higher than the other persons of the study group.

In the calculation of the absorbed dose, only the nationwide average was considered. The radiation doses were calculated with regard to cesium-137, and table 9 shows the doses to the gonads in mrad/a, where the values in table

Table 9. Absorbed doses to the gonads from cesium-137 deposition in the body

Year	Dose (mrad/a)
1962	2.4
1963	4.3
1964	6.8
1965	5.4
1966	3.3
1967	2.1
1968	1.6

3 for the yearly intake of cesium-137 were used. The corresponding mrad value was calculated by using the factor 9.5 mrad/a per nCi/kg (77). The absorbed dose rate from the body burden of cesium-137 had its maximum at 6.5 mrad/a in 1964 and the total dose during the period 1960-1970 will be 31 mrad, if the radioactivity continues to decrease according to the pattern of the past few years. As a comparison, the maximum dose rate to the Lapps was, on the average, about 100 mrad/a in 1965.

The external irradiation can be estimated from the measured radiation exposures presented in table 5. However, large uncertainties are involved in such an estimation because of the wide variations in screening of radiation by house walls, washout of activity from asphalted streets, etc. With a correction factor of 0.2 (64) for the screening, etc., the external doses are obtained according to table 10.

Table 10. Absorbed dose from external exposure due to fallout

Year	Absorbed dose (mrad/a)
1960	2.6
1961	3.8
1962	2.3
1963	1.8
1964	1.8
1965	1.6
1966	1.8
1967	1.6
1968	1.8

UNSCEAR (63) gives a factor of 0.008 mrad/a per mCi ¹³⁷Cs/km² for the calculation of the dose to the gonads caused by gamma radiation from fallout on the ground. According to measurements in Sweden (60, 61) the amount of cesium-137 deposited since 1966 is 55 mCi/km² and the calculated dose is 0.44 mrad/a. The factor 0.008 is the product of 0.2 and 0.04. The correction factor for screening, etc., is 0.2, and the factor in air is 0.04 mrad/a per mCi/km². This factor was accepted by UNSCEAR in 1966 on the basis of the results from Beck (78) and Gustafson (79). Earlier the factor was assumed to be 0.12. Lindell (80) showed by theoretical calculations that if the activity was deposited on an infinite plane the factor is 0.06 mrad/a per mCi/km² at 1 meter above ground, disregarding the absorption in the ground and buildup in the air. Hence, the factor 0.12 includes a buildup factor ≥ 2 and an absorp-

tion factor ≤ 1 . With this factor, the calculated dose is 1.3 mrad/a, which is in better agreement with the measured values. However, the agreement could be a coincidence. The accumulated fallout on the ground since 1966 is said to be 55 mCi/km² as an average for Sweden. There are, of course, local variations and the accumulated radioactivity on the ground close to the measuring stations is not known.

The total natural radiation to the gonads is about 100 mrad/a in Sweden, with variations between 50-300 mrad/a (81). Thus the external radiation caused by fallout was, at the most, 4 percent (1963) of the natural radiation to the gonads. The additional internal irradiation due to cesium-137 was, at the most, 7 percent (1964). The total irradiation to the gonads due to cesium-137 in the body and the external irradiation from the ground during 1960 to 1970, will be about 5 percent of the natural irradiation.

Because of the low radiation doses caused by fallout activity, even to those who had experienced the highest exposures, no remedial action has been considered justified. Any reasonable action to reduce the exposure, such as, changing the dietary habits, also involves certain risks which are likely to be more serious than the effect of the radiation dose. As already mentioned, there were also large variations in natural irradiation and, as a rule, the additional radiation doses caused by fallout have fallen within the extreme limits of the values from natural radiation.

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Environmental Survey of Uranium Mill Tailings Pile, Monument Valley, Ariz.

Robert N. Snelling¹

At the request of the Navajo Tribal Council through the Public Health Service Division of Indian Health at Window Rock, Ariz., an environmental radiological survey was conducted on the Foote Mineral Company's uranium tailings pile, Monument Valley, Ariz., in May 1968. The purpose of the survey was to identify any radiation hazards which might exist and recommend methods for their control. The survey included evaluation of external gamma radiation, airborne radioactivity, and waterborne radioactivity.

The results of the survey indicate that existing radiation levels do not exceed recommended exposure limits. However, to minimize the possibility of increased activity from weather conditions different from those existing during the survey, it was recommended that the mill tailings be stabilized against wind erosion. Otherwise, periodic monitoring will be necessary in the future.

In April 1968, the Division of Indian Health requested the Bureau of Radiological Health to conduct a study of the Foote Mineral Company's (FMC) tailings pile located at Monument Valley, Ariz., to identify any radiation hazards which might exist and recommend methods for their control. In response to this request, the tailings area was surveyed in May 1968.

The mill site is located on the Navajo Indian reservation approximately 17 miles from Mexican Hat, Utah. The property is leased to the milling company by the Navajo Tribal Council. The surrounding land is arid and sparsely populated, although there are several private dwellings within one-half mile of the tailings area. The land is utilized primarily for cattle and sheep grazing with some limited farming. The mill was designed and operated for the upgrading of low grade uranium ore and is at present inactive. The mill property is divided into two areas: the tailings and stockpile area, and the housing area.

The original tailings pile was reprocessed for recovery of uranium and disposed in a new location. The old tailings area, the ore stockpile area and the present tailings pile are shown in figure 1. The present tailings pile covers approximately 25 acres and contain an estimated 1.5×10^6 tons of tailings material.² The radium content estimated

from the average uranium assay of mill feed material (assuming radium in equilibrium with uranium) is approximately 90 pCi/g or a total of 122 curies.²

There are several dwellings located in the vicinity of the old mill and tailings area. One dwelling was occupied by the mill superintendent during the period of the survey.

Sampling procedures

External radiation measurements were obtained using a portable Geiger survey meter. Gamma (closed window) readings were obtained at the surface and at the 3-foot level. A grid was established over the area and readings obtained at 250-foot intervals. A total of 82 pairs of readings was recorded.

In addition to the portable instrument readings, three thermoluminescent dosimeters (TLD) were placed at the 3-foot level at each of the air sampling stations and inside the mill superintendent's house (figure 1). The TLD's respond only to gamma radiation.

Wind direction and speed were estimated by visual observation. The predominant wind direction at the mill site for the 10-day sampling period was from the south. According to FMC personnel, this is the predominant wind direction throughout the year. During the first 6 days of

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² Division of Raw Materials, USAEC, 1967.

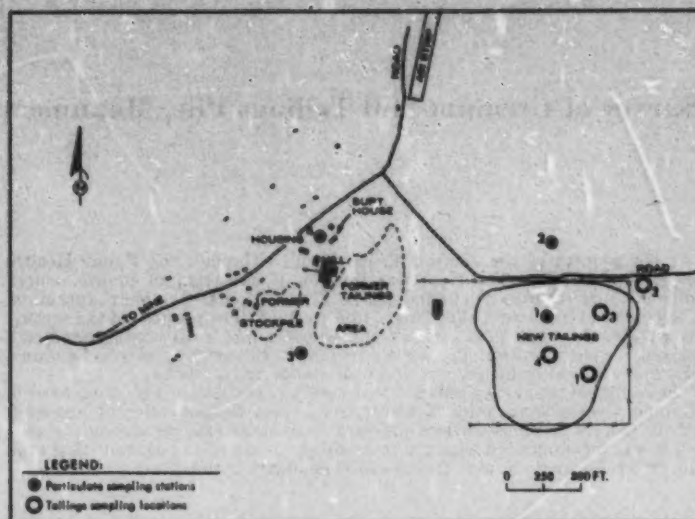


Figure 1. Air and tailings sampling locations, Monument Valley uranium mill

sampling the wind was light (0-5 mph). During the last 4 days, however, winds estimated at 10-20 mph were encountered. In general, lapse conditions were encountered during daylight hours with slight inversions at night.

Long-lived airborne particulate radioactivity was sampled by drawing air through a 0.8-micron pore size filter. A high-volume air sampler was used at a flow rate of about 5 cubic feet per minute. Four sampling stations were established on and about the tailings area (figure 1). Continuous 24-hour samples were obtained at stations 1, 2, and 3 on each of 10 consecutive days. Since electric power was available only between the hours of 4:30 p.m. and 8:30 a.m. at station 4, the air at this station was sampled only during this 16-hour period. Each individual filter was analyzed for gross long-lived alpha radioactivity. In addition, all filters from each station were composited for analysis of radium-226, thorium-230, and natural uranium.

Atmospheric samples for radon gas were obtained by grab sampling with a 2-liter flask. The stopcocks of the flask were opened and air was pulled through the flask for 5 minutes at a rate of 10 liters per minute after first passing through a 0.8-micron pore size membrane filter. At the end of the sampling interval, the flask was allowed to come to atmospheric pressure and the stopcocks were closed. The samples were picked up by the

Public Health Service aircraft and flown to Las Vegas, Nev., for immediate analysis of radon-222. Samples were collected at six locations on one or more occasions for a total of 11 samples (figure 2).

Ground water samples were obtained from five wells in the area. One-gallon grab samples were obtained and analyzed for radium-226 and natural uranium activity.

Samples of tailings material were collected at the locations indicated in figure 1. Approximately 400 cc of surface material were taken from each location. The samples were analyzed for thorium-230, radium-226, and natural uranium.

Analytical procedures

All laboratory analyses were performed at the Southwestern Radiological Health Laboratory. Gross alpha and gross beta radioactivity determinations were performed after sample preparation by counting directly in an end-window, gas flow proportional counter. Radon-222 analysis was performed by cryogenic separation and subsequent alpha-particle scintillation counting. Radium-226 was determined after sample preparation by the radon emanation technique; uranium analysis was accomplished by the fluorometric technique; and thorium-230 analysis was performed by means of solvent extraction and subsequent alpha-particle counting.

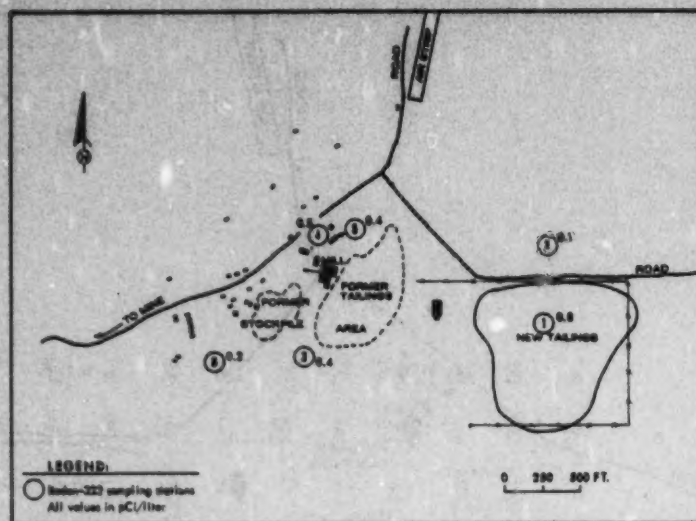


Figure 2. Atmospheric radon-222 sampling stations, Monument Valley uranium mill

Table 1. External radiation measurements, Monument Valley uranium mill, May 1968

Area	Number of measurements	Radiation at surface (mR/h)		Radiation at 3 feet (mR/h)	
		Average	Range	Average	Range
Background.....	6	0.04	0.03-0.06	0.04	0.02-0.06
Housing area.....	8	.04	.02-.07	.04	.01-.05
Tailings and stockpile area.....	50	.09	.02-.3	.06	.03-.2
Perimeter.....	18	.03	.02-.04	.03	.01-.04

Results

Table 1 summarizes the gamma radioactivity measurements obtained at the surface and at 3 feet for the various areas. Figure 3 indicates the location and magnitude of individual measurements. The background radiation level in the surrounding areas was found to average 0.04 mR/h both at the surface and at 3 feet. The radiation exposure at the 3-foot level in the tailings and stockpile area was found to range from a minimum of 0.03 mR/h to a maximum of 0.2 mR/h with an average of 0.08 mR/h. There was no significant difference between the readings at 3 feet and those at the surface. The radiation exposure at 3 feet in the housing area was found to average 0.04 mR/h. This exposure represents normal background levels of radiation. Measurements made along the perimeter of the property (approximately 200 feet from

the fence) averaged 0.03 mR/h. This represents background levels of exposure. A comparison of the results obtained from the TLD's and the portable instrument measurements is shown in table 2. The results are in good agreement.

Table 2. Comparison of TLD and Geiger meter data, Monument Valley uranium mill, May 1968

Station number	Radiation measured by (mR/h)	
	TLD	Geiger meter
1.....	0.07	0.07
2.....	.02	.02
3.....	.05	.06
4.....	.09	.07
Inside superintendent's house.....	.05	.12

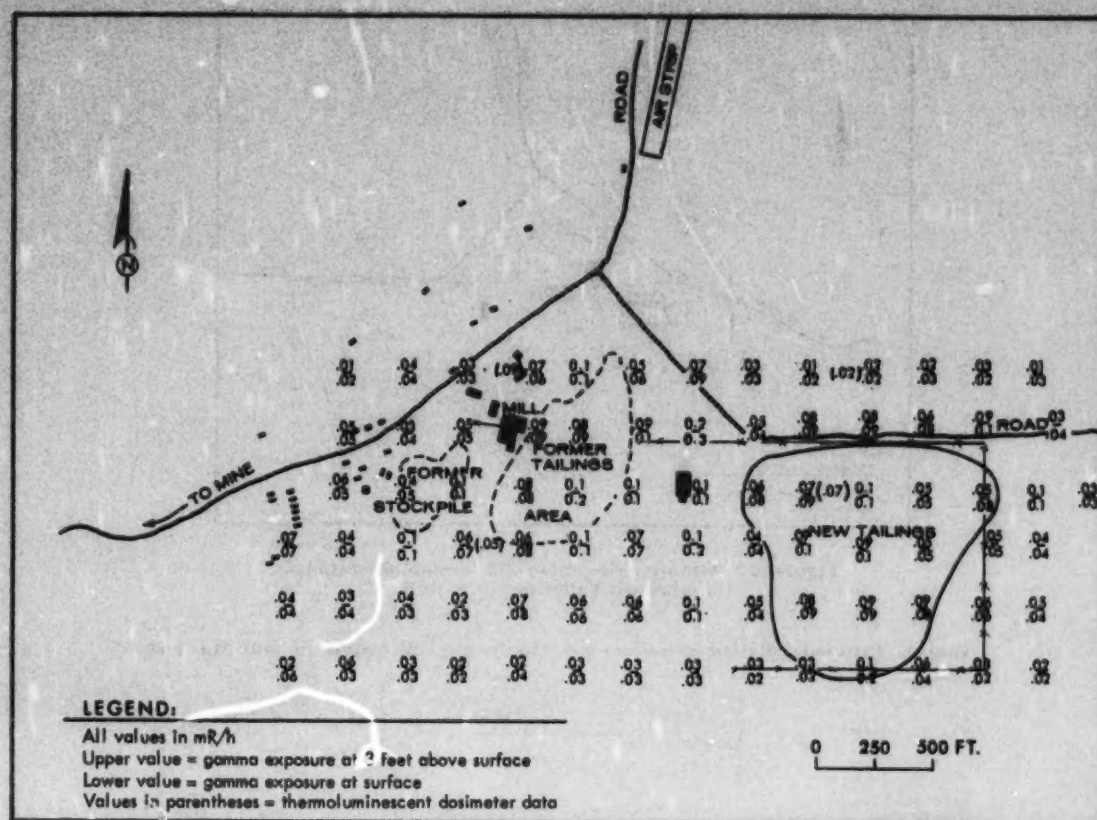


Figure 3. External radiation measurements, Monument Valley uranium mill

Table 3. Gross long-lived alpha radioactivity of particulates in air, Monument Valley uranium mill, May-June 1968

Station number	Gross alpha radioactivity (fCi/m ³)										Six day average ^a	Total average ^a
	May 1968			June 1968								
	29	30	31	1	2	3	4	5	6	7		
1	21	<10	<10	12	(*)	52	424	(*)	(*)	(*)	18	103
2	<10	22	79	<10	<10	<10	395	55	(*)	(*)	14	70
3	36	<10	<10	71	<10	<10	(*)	(*)	(*)	(*)	16	16
4 ^d	10	79	33	<10	<10	21	499	35	338	40	23	100

^a Average is weighted in accordance with sample volume collected.

^b Assumed equal to zero for averaging.

^c Sampler failure.

^d Samples collected between 1630 and 0630 m.s.t.

The long-lived gross alpha radioactivity on particulates found on individual filters is shown in table 3. The upwind station (No. 3) averaged 16 fCi/m³ gross alpha radioactivity over the first 6 days. No valid samples were obtained from station No. 3 during the last 4 days because of re-

current sampler failure. The downwind stations showed no significant difference from station No. 3 during the first 6 days. During the last 4 days, when strong winds were encountered, a significant increase in alpha radioactivity was noted for all three downwind stations. The average gross alpha

Table 4. Average long-lived radioactivity in air, Monument Valley uranium mill, May 1968

Station number	Gross alpha (fCi/m ³)	Radium-226 (fCi/m ³)	Thorium-230 (fCi/m ³)	Natural uranium (ng/m ³)
1	103	23	45	63
2	70	5	7	12
3	16	1	6	14
4*	103	8	11	40

* Sample collected between 1630 and 0630 m.s.t.

radioactivity for the total collection period for downwind stations ranged from 70 fCi/m³ at station 2 to 103 fCi/m³ at stations 1 and 4.

Table 4 shows the average gross alpha radioactivity along with radium-226, thorium-230, and natural uranium activity for each station for the entire sampling period.

Table 5 summarizes the radon-222 activity concentrations found at specified sampling times and locations. Figure 2 shows the average radon concentrations at each sampling location.

Table 5. Atmospheric radon-222, Monument Valley uranium mill, May 1968

Station number	Radon-222 (pCi/liter)			
	5/28, 1445 m.s.t.	6/3, 1000 m.s.t.	6/6, 1000 m.s.t.	Average
1	0.5	0.4	1.5	0.8
2	.1			.1
3	.3	.4		.4
4		.5		.5
5				
(inside house)	.7	.4	.2	.4
6 (background)	.2			.2

Table 6 summarizes the average radium-226 and natural uranium results for the five water sampling stations. Stations 3 and 5 can be considered as background stations because of their distance from the tailings area. There is no significant difference between the samples taken in the vicinity of the pile and background samples.

Table 6. Radioactivity in ground water, Monument Valley uranium mill, May 1968

Station number	Location	Number of samples	Radium-226 (pCi/liter)	Natural uranium (μg/liter)
1	Superintendent's house, well	1	0.1	18
2	Luke Yasse's well, 1/4 mile south	1	.2	6
3	Tom Adair's well, 1/4 mile east	1	.1	4
4	Tony Yasse's well, 1/4 mile east	1	1.5	ND
5	Cain Valley Spring, well 4 miles north	1	.5	2

Table 7 summarizes the results of the thorium-230, radium-226, and natural uranium analyses on tailings material. The radium content on the tailings samples averaged 59 pCi/g. This average is somewhat below that predicted from the average assay of mill-feed material (90 pCi/g). The thorium-230 averaged 46 pCi/g and natural uranium averaged 33 μg/g (0.003 percent). A soil sample taken 100 feet northeast of the pile displayed results of the same order of magnitude.

Discussion

The code of Federal Regulations, Title 10, Part 20, indicates a maximum allowable whole body dose to an individual in an unrestricted area of 0.5 rem in any period of 1 calendar year. The regulations further indicate a maximum allowable dose for continuous exposure to individuals in an un-

Table 7. Tailings sampling, Monument Valley uranium mill, May 1968

Area	Number of samples	Uranium (μg/g)		Thorium-230 (pCi/g)		Radium-226 (pCi/g)	
		Mean	Range	Mean	Range	Mean	Range
Tailings pile	3	33	17-49	46	28-56	59	48-77
100 feet NE of pile	1	18	—	27	—	31	—

restricted area of 2 millirems in any 1 hour or 100 millirems in 7 consecutive days.

The Radiation Protection Guide (RPG) adopted by the Federal Radiation Council recommends that the yearly radiation exposure to the whole body of individuals in the population (exclusive of natural background and the deliberate exposure of patients by practitioners of the healing arts) should not exceed 0.5 rem (1). The council further recommends, however, that every reasonable effort should be made to keep exposures as far below this level as possible.

To evaluate the potential long-range hazard associated with the external radiation emitted from the tailings material, the average yearly whole body exposure for an individual having 24-hour per day residence on the area was calculated and compared to the recommended RPG of 0.5 rem/a. The net gamma radiation (i.e., minus background) at 3 feet was used for this computation.

The average exposure at the 3 foot level on the tailings and stockpile area was found to be 0.08 mR/h. The whole body average yearly dose for an individual having 24-hour per day residence on the tailings would be approximately 0.35 rem/a (calculated from the average net exposure of 0.4 mR/h). This dose is less than the RPG of 0.5 rem/a. The highest single measured exposure of 0.2 mR/h (0.16 mR/h net) at 3 feet would result in a yearly dose of 1.1 rem for continuous exposure. This is two times the RPG of 0.5 rem/a but represents the unlikely condition of continuous occupancy. With reasonable occupancy assumptions, it would not be expected that a yearly average dose in excess of 0.5 rem would occur. The housing area showed background levels of exposure.

In order to assess the potential long-range health hazard associated with the inhalation of airborne radionuclides, the average radioactivity concentrations on airborne particulates observed for each sampling station were compared to the recommended radiation concentration guides as indicated in The Code of Federal Regulations, Title 10, Part 20. Because the guides are applicable to yearly average concentrations, this comparison assumed that the meteorological conditions imposed during the sampling period were representative of the yearly average conditions.

The Code of Federal Regulations, Title 10, Part 20, indicates a radiation guide for unidentified

natural radionuclides in air of 80 fCi/m³ (when protactinium-231 is assumed absent). If gross alpha radioactivity is above this guide, identification of the specific radionuclides contributing to the total alpha radioactivity is necessary in order to evaluate the potential long-range hazard associated with the inhalation of the airborne particles.

The nuclides in the natural uranium decay chain most significant as potential health hazards are the alpha-particle emitters. These nuclides and their appropriate guides are:

Thorium-230 (soluble)	80 fCi/m ³
Radium-226 (insoluble)	2 pCi/m ³
Natural uranium (insoluble)	2 pCi/m ³
Lead-210 (soluble)	4 pCi/m ³
Polonium-210 (insoluble)	7 pCi/m ³

It is apparent from comparison of these values with table 4 that none of the stations exceeded the guides for individual radionuclides for the sampling period. As expected, the station showing the highest concentrations was station 1 located directly on the tailings pile. At this station, radium-226 and natural uranium averaged factors of 100 and 30, respectively below their appropriate guide. Because of the low concentration of these nuclides in the tailings material it is not expected that these nuclides will exceed their guides downwind from the pile in the future.

Thorium-230 for station 1 averaged 45 fCi/m³. The other stations showed average thorium-230 concentrations ranging from 6 fCi/m³ at station 3 to 11 fCi/m³ at station 4. It is doubtful that concentrations downwind from the pile would exceed the guide of 80 fCi/m³ averaged over an extended period of time. However, it is impossible to predict this absolutely on the basis of less than 10 days of sampling.

The Code of Federal Regulations, Title 10, Part 20, indicates a radiation concentration guide for radon-222 in air in unrestricted areas of 3 pCi/liter above natural background. The daughters of radon-222 are assumed to be present to the extent that they exist in unfiltered air. (This is interpreted as meaning equilibrium conditions.) To evaluate the potential long-range hazard associated with the inhalation of radon and its progeny, the atmospheric radon concentrations were compared to this guide.

None of the radon samples collected on or about

the tailings area was above the recommended guide.

Ground water samples obtained in the vicinity of the tailings area showed background levels of radioactivity.

Summary

The net external gamma radiation on the tailings and stockpile area averaged 0.04 mR/h at 3 feet above the surface. This calculates to a yearly dose of 0.35 rem/a for continuous exposure and does not exceed the recommended Radiation Protection Guide (RPG) of 0.5 rem/a for continuous whole body exposure to individuals in the general population.

The housing area showed background levels of radiation.

The stations located downwind from the tailings area showed gross alpha concentrations on airborne particulates approximately equal to or in excess of the concentration guide (RCG) of 80 fCi/m³ for unidentified alpha radioactivity. None of the stations exceeded the guides for radium-226, thorium-230, or natural uranium, however.

Radium-226 and natural uranium averaged a factor of 100 and 30, respectively, below their appropriate guide. Because of the low concentration of these nuclides in the tailings material, it is not expected that these nuclides will exceed their guides downwind from the pile in the future.

Thorium-230 concentrations averaged from one-tenth to one-half the concentration guide of 80 fCi/m³ for the downwind stations. Although it is doubtful that concentrations downwind from the pile would exceed the concentration guide averaged over an extended period of time, this is impossible to predict on the basis of less than 10 days of sampling. On this basis it was recommended that the tailings pile be stabilized against wind erosion. This would preclude the possibility of exposure to thorium-230 in the future. If the pile is not stabilized, periodic sampling will be necessary to insure that concentrations of thorium-230 in air do not exceed the guide over an extended period.

Radon gas concentrations on and about the tailings area averaged approximately an order of magnitude below the guide of 3 pCi/liter.

Ground water samples obtained in the vicinity

of the tailings area showed background levels of activity.

Recommendation

On the basis of the data gathered in this survey it was recommended that the mill tailings be properly stabilized against wind erosion. This action would preclude carriage of tailings material into the surrounding environment and would minimize any potential long-term hazard to anyone inhabiting the area downwind from the mill property. If the tailings area is not stabilized, periodic surveillance will be necessary to insure that significant wind carriage does not occur.

Followup

This study was conducted as part of the Uranium Mill Tailings Project being conducted at the Southwestern Radiological Health Laboratory. The objectives of the project are to gather information on the potential health hazards associated with uranium mill tailings and to institute control action where necessary.

The recommendations made following the survey of the uranium mill tailings pile at Monument Valley, Arizona, were forwarded to the Division of Indian Health and to the State of Arizona in preliminary form in November 1968. As of this writing, no action has been taken on the recommendations.

Acknowledgments

Sincere appreciation is expressed to the Foote Mineral Company for the cooperation and assistance provided during the survey. Without their cooperation, the study could not have been adequately performed.

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Results of a Study of Color Television Set Assembly and Repair Workers X-Ray Safety

Stanley D. Savic¹

A study was conducted to determine the degree of exposure of television set assemblers and repairmen to low levels of low energy x radiation. Two independent companies supplied the x-ray film badges on a biweekly basis. In addition, some television repairmen were also asked to wear thermoluminescent (TLD) ring badges so that the degree of hand exposure to x rays could be determined. In two large service shops, detailed records were also kept of the number and models of television receivers which were serviced. The largest total exposure recorded by film badges worn by any repairman during the one and a half year duration of the survey, was 34 mR. During that same time, no other badge showed any radiation, and therefore, we assume that this one film was inadvertently exposed to heat or some other element. In a later survey, there were a few scattered hand exposure readings ranging from 16 to 70 mR for TLD rings which were continuously worn over a 3-month period. These readings are also suspected to be false, because they were not repeatable with the same individuals and because hundreds of other TLD rings registered no dosage. During the 8 months duration of the factory assemblers' survey, over half a million color television receivers were produced by the 1,000 monitored employees. Not a single film badge worn in the factory assemblers' survey showed any radiation. We conclude that occupational x-radiation exposure of television repairmen and assemblers is virtually nonexistent.

At the Conference on Detection and Measurement of X-Radiation held in March of 1968, a paper (1) was presented which described preliminary results of a study into the x-radiation safety of television repairmen. That study has now been completed, and it is the purpose of this paper to give a full report of its findings. The results reported here will also summarize findings of an extensive color television factory assembly line personnel survey and monitoring program. This was done in the hope that it may cast some new light on the subject of x radiation from home television receivers, as well as provide helpful data to future researchers. These studies were initiated because we were unaware of any previously reported broad studies into TV repairmen's and TV factory assemblers' safety from possible exposure to low energy x radiation.

Background

The potential hazards of byproduct x-radiation emission from color television receivers to viewers

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have been the subject of numerous studies in the past. Guidelines were issued by the National Committee on Radiation Protection and Measurements (NCRP) in 1959 which arbitrarily established a recommended limit for x-ray emission from any normally operating home television receiver at 0.5 mR/h at any readily accessible point 5 cm from the surface (2). Although these guidelines have generally been observed by most manufacturers of television receivers, under certain conditions of high voltage regulation circuit maladjustments or failures which result in an abnormal increase in the high voltage, perhaps aggravated by high line voltages, some receivers were capable of exceeding the NCRP recommendation. The failures in high voltage regulation circuitry usually result in some other circuit or component failure which demonstrates itself to the viewer in one or more of several ways. These may take the form of a completely nonoperative receiver, periodic arcing accompanied by loud noise, or a repeated failure of some other component which thereby warrants much more frequent servicing (in home tube replacement, for instance). Most of these conditions ultimately necessitate

servicing of such a receiver in a service shop or a close examination of the receiver by the field serviceman in the user's home, and that is why we were interested in investigating the risk involved for television servicemen.

During the time of exposure, the user of such a receiver would be expected to be subjected to a lower exposure rate than that measured at close proximity to the set's surface. This is due to the rapid decrease of x-ray intensity with viewing distance. Intensity is reduced by a factor of approximately five for each meter in the direction away from the picture tube, and thus the total dose actually received at recommended viewing distances may be regarded as negligible. Without further study, the same could not have been said for the repairmen who must work in very close proximity to the components capable of emitting x radiation and also for factory assemblers who work in very close proximity to operating receivers or operating sections of the receiver chassis during certain factory tests. Finally, concern should also be given to the factory repairmen who work on sets rejected from the assembly lines because of faulty wiring which in some sets may result in elevated high voltage and possibly, in x radiation. These are the reasons we undertook our study.

Not every failure of a television set component will result in elevated high voltage or in additional x-ray exposure to the repairmen. In fact, the high voltage circuit of a television receiver is in many ways, one of the more reliable sections, and repairs generally amount to no more than the replacement of a vacuum tube. As wider use is made of solid state components in domestic TV receivers, time necessary for repair may increase also. However, it is anticipated that in the future, solid state devices, still in the developmental stage, may also be used for generation of picture tube operating voltages so that high voltage shunt regulator and high voltage rectifier vacuum tubes may be eliminated. These vacuum tubes were shown (3-5) to be major possible sources of x radiation in color television receivers.

At the time our surveys were conducted, Zenith Radio Corporation was no longer using high voltage shunt regulator tubes (6BK4) in television sets. Phasing out of these tubes began in 1966. The newer sets use a low voltage pulse regulator tube (6HS5) which does not emit x rays. This, however, does not detract from the validity of our

repairman survey since a large percentage of the sets which were serviced in the three monitored repair shops had been produced prior to 1966. The exact percentage of receivers with shunt regulator tubes will be discussed below. The factory assembly workers, however, were not exposed to any sets with high voltage shunt regulator tubes. Their accumulated x-ray dose, if any, could only be due to rectifier and picture tube radiation, and therefore, their data must only be considered representative of the present conditions.

Film badge monitoring of assembly workers

For this survey, we employed the services of R. S. Landauer, Jr. & Company which provided us with clip-on x-ray film badges. These badges were issued to all employees who worked with, or in close proximity to, energized color television receivers or receiver chassis. Each film badge was worn for a period of 2 weeks in order to assure that even low levels of radiation accumulation could be detected. At the end of each working day, all badges were deposited in a previously designated place and reissued each morning. Male employees were instructed to wear the film badges clipped to either their shirt pockets or belts. Female employees were instructed to wear the badges clipped to their blouses or sweaters. This program was initiated on March 11, 1968, and lasted through November 17, 1968, at which time it was discontinued because not a single film badge showed any radiation at or above the minimum detectable exposure.

The total number of x-ray film badges worn by employees was 15,159. Since each film badge was worn for 10 working days, this amounted to a total of 151,590 film badge work days without any indication of radiation exposure in addition to that which is attributed to natural background radiation. The total number of color television receivers produced by all three Zenith plants which participated in the program was over half a million. This is summarized in table 1.

Table 1. Summary of information on film badge monitoring of color television receiver assembly workers

Duration of survey	March 11 to November 17, 1968
Number of work days (excluding holidays)	161
Average number of employees participating	940
Total number of film badges worn	15,159
Number of work days each badge was worn	10
Total number of film badge work days	151,590
Maximum exposure reported on any badge	0

Thermoluminescent dosimeters used in the factory

At the end of the factory film badge survey, 162 production line color television repairmen were asked to wear thermoluminescent (TLD) ring badges for two consecutive periods of 3 months each. This was done in order to determine if any hazards exist from hand exposure to malfunctioning sets. These badges were also supplied by R. S. Landauer, Jr. & Company. Individuals who were asked to wear the LiF ring badges were the same ones who had already participated in the earlier film badge survey. It should be noted that a factory repairman works on considerably more sets in any single day than does a field serviceman and that the total exposure equals the exposure rate multiplied by the time. Typically, a factory repairman works on 30 malfunctioning sets per day. The number of sets worked on by a field repairman would, because of travel time, generally be less than 10 per day. Factory failures encountered are very similar in nature to field failures. Table 2 gives the summary of results obtained during this survey which lasted from October 1, 1968, to March 31, 1969.

Table 2. Results of TLD ring badges worn by factory repairmen for 6 months

First 3 months		Second 3 months	
Number of badges	Reported badge exposures (mR)	Number of badges	Reported badge exposures (mR)
* 1	70	1	20
* 3	20		
* 8	10		
124	0	100	0
26	Destroyed or Missing	52	Destroyed or Missing
162 Total		162 Total	

* Each one of these badges showed no radiation in the second 3-month period.

From the results of the survey, one can see that, except for a single reported 3-month exposure of 70 mR, there were no readings higher than 20 mR, and none of the readings above background for the first quarter were repeatable during the second quarter. We attempted to arrive at an explanation for these readings but were unsuccessful. The wearers were allowed to take their ring badges home, and this may hold the explanation for destruction or loss of a substantial number of badges. We know that most employees found the ring badges a nuisance and were not too enthusiastic

about wearing them. This may also explain the fact that the number of lost badges doubled during the second quarter. For that reason, we suggest that future researchers consider the use of a less cumbersome wrist TLD badge to monitor hand radiation.

Service shop survey

When it was first reported that a major color television manufacturer had become involved in an extensive recall program because of allegedly excessive amounts of x radiation which were emitted from certain models, we initiated a complete review of television receiver x-radiation safety. One of the first items was to visit several independent and several manufacturer-affiliated service shops. The list of questions of interest during those visits is shown in figure 1. In none of the shops did we come across a "problem", but we found that not all of the manufacturers' recommendations were always followed. This was particularly true with respect to measurements and adjustment of high voltage.

We next concentrated on three Zenith-affiliated large service shops. Two of the shops are located in Chicago, Ill., and the third one is in New York City, N.Y. Initially, we conducted an inspection of each of the three shops to determine those conditions which had to be considered for each shop and how many film badges would be required to adequately monitor x-radiation levels there. All film badges used in this survey were supplied by Nuclear Chicago Corporation which also read the badges and then sent the results to us. Previously, we had instructed Nuclear Chicago Corporation to interpret all their film density readings for the type of radiation which we anticipated; i.e., 25-35 keV x rays. The badge-wearing period was initially set at 1 week, but when the first few reports came in without any reported exposure, the wearing period was increased to 2 weeks. In addition to personnel badges which all color receiver repairmen were instructed to wear clipped to their shirt pockets, we also used in each shop five "area monitoring" film badges and one "control" badge. The "area monitoring" badges were positioned throughout the service shops on bench tops and other areas where one or more television sets could operate simultaneously while being repaired. The "control" badge was always kept sufficiently away

FIELD INSPECTION REPORT

DATE: _____ COMPANY: _____

ADDRESS: _____

INSPECTION MADE BY: _____

WAS FIELD REPRESENTATIVE PRESENT? _____

1) HOW MANY PERMANENT SETUPS OR JIGS EXIST? _____

2) WHAT KIND? (DESCRIBE BRIEFLY) _____

IF ANY X-RAY MEASUREMENTS ARE MADE ON THESE SETUPS, DESCRIBE
THE RESULTS: _____

3) HOW MANY SERVICEMEN ARE EMPLOYED WHO WORK ON COLOR TV? _____

4) DO THEY ADJUST HV ON EVERY SET? _____

5) IF NOT, WHEN DO THEY ADJUST IT? _____

6) DO THE FIELDMEN ADJUST HV WITH A METER? _____

7) ARE SERVICEMEN OR MANAGER AWARE OF POTENTIAL X-RAY HAZARDS? _____

8) DO THEY REINSTALL SHIELDS? _____

9) DO THEY NOTICE HIGHER HV (ABOVE 27KV) ON SETS THAT COME IN? _____

10) WHAT IS THE LINE VOLTAGE IN THE SHOP? _____

11) DO THEY ADJUST HV FOR 25KV OR IF AC LINE IN THE SHOP IS TOO HIGH
OR TOO LOW, DO THEY COMPENSATE ACCORDING TO THE MANUAL? _____

12) DO THEY EVER "COOK" SETS AT ELEVATED HV OR LINE VOLTAGE? _____

Figure 1. Service shop survey form used to learn about servicing habits of color television repairmen

from any operating sets and was used to account for any possible false radiation reading which could be indicated by badges in transit.³ As it turned out, two such shipments apparently did register false indications. In one shipment, all badges including the control badge showed between 30 and 42 mR. In the other shipment, the range was between 47 and 60 mR for all badges including the control badge.

The repairman survey was conducted continuously from July 10, 1967 to January 6, 1969. A total of 628 personnel film badges was worn by 18 color television repairmen for an accumulated 6,973 film badge work days. During the same period, a total of 586 "area monitor" film badge dosimeters was used. These area monitor film badges accumulated a total of 5,628 badge work days.

In order to better understand the significance of these film badge reports, detailed records were kept in the New York shop and in one of the Chicago shops. These records included chassis model numbers of each receiver worked on as well as the total number of each chassis type worked on. In the form (figure 2) used for this purpose the numbers in the column just to the left of the chassis model numbers refer to how many of each type of chassis were worked on in the shop. (The servicemen did not wear their film badges out of the service shops during home calls.)

From the information collected in the two shops we estimated that over 5,000 television receivers were repaired in the three shops by servicemen while they wore their film badges. Approximately 18 percent of these were of the shunt regulator type.

An "Excessive Film Badge Radiation Report Form" (figure 3) was used for this survey to enable a permanent record of the circumstances under which an individual may have received an overexposure. As it turned out, only one film badge showed a measurable radiation exposure, and that was 34 mR for 2 weeks. The only unusual fact about this badge was that it was worn during the month of August inside the pocket

where humidity and temperature could conceivably combine to increase the fog level, but our conclusion that this was a false reading attributable to excessive heat and humidity can at best be accepted as only a guess (6).

Table 3 summarizes all of the data obtained for both the "personnel" and "area monitoring" film badges.

Table 3. Results of survey of three service shops in which television repairmen wore x-ray film badges for 1½ years^a

Number of personnel badges	Exposure (mR)	Number of area monitor badges ^b	Exposure (mR)
1 627	34 0	2 384	1 0

^a Number of "personnel" film badge days, 6,973. Number of "area monitor" badge days, 5,628. Number of receivers serviced (approximately), 5,000.

^b Film badges were worn for 2-week periods.

Conclusions

Based on the results of these surveys, it is this writer's considered opinion that the potential for an accidental overexposure to low energy x radiation from home television receivers to television assemblers and repairmen is negligible and virtually nonexistent. Even if the highly suspicious unique readings are accepted as accurate, the maximum amount of radiation which could be attributed to occupational hand exposure observed for an individual would be 70 mR during a 6-month period, which is equivalent to 140 mR/a, and the maximum total body exposure of an individual during a period of 1½ years was 34 mR, which is equivalent to 22.5 mR/a. The arithmetic mean of the annual serviceman hand exposure due to television radiation as calculated from data presented in table 2 is equivalent to 1.9 mR/a. Similarly, from table 3, one can calculate the arithmetic mean for annual total body x-ray exposure of television servicemen to be less than 1 mR/a. It must be pointed out that there is almost no meaning in calculating the average x-ray exposures of servicemen since from these data one cannot construct an actual distribution curve; however, if calculation of such an average exposure were necessary, the answer would have to be zero radiation within the limits of measurement. The arithmetic means calculated from tables 2 and 3 are negligible when compared with recommendations issued by the International Commission on

³ There are many reasons why a film badge might show exposure from causes other than radiation. These are heat, chemical fumes, etc., and they must be excluded if the reading is to be meaningful. On the other hand, if the badge shows no exposure, then one may assume that there has been no x-ray exposure.

December 12, 1968

SERVICE LOCATION: 912 W. Washington

DATE SHOWN ON BADGES: 11/25/68

<u>BADGE NUMBER</u>	<u>NAME</u> (Purposely Deleted)	<u>CHASSIS</u> <u>WORKED ON</u>
63313-08		6 16Z7C50 2 20Y1C50 1 20X1C38
63313-09		4 16Z7C50 1 20X1C38 5 20Y1C50 2 25NC37
63313-10		15 16Z7C50 11 20Y1C50 2 20Z1C37 1 15Y6C15 1 25NC37 4 23X1C38
63313-11		1 20X1C38 5 20Y1C50 6 16Z7C50 4 15Y6C15
63313-12		10 16Z7C50 2 20Y1C50 3 24NC38
63313-13		6 15Y6C15 11 16Z7C50 5 20Y1C50 2 20Y1C38
63313-26		1 20Y1C38

MANAGER
(Name Deleted)

Figure 2. Example of a completed form used to determine number and types of chassis serviced during survey

EXCESSIVE FILM BADGE RADIATION REPORT FORM

Date: _____

Film Badge Company: _____

Badge Worn By: _____ Age: _____

From: _____ To: _____

Reported Dose: _____ mR

Type Of Radiation: _____

Total Body: _____ Other: _____ (Explain) _____

Wearer's Explanation: _____

Notes: _____

Figure 3. Reporting form used to document case history of each film badge that showed any x-ray exposure

Radiation Protection and the National Committee on Radiation Protection (7). Development of high voltage solid state devices, incorporation into rectifier and shunt regulator tube glasses of high x-ray absorbing materials such as lead, and replacement of barium in color picture tube panels by strontium, presently under way, will in our opinion even further reduce the already negligibly small exposure hazard.

Acknowledgment

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Elevated Levels of Cesium-137 in Common Mushrooms (*Agaricaceae*) with Possible Relationship to High Levels of Cesium-137 in Whitetail Deer, 1968-1969

Wallace Johnson¹ and Chester L. Nayfield²

High levels of cesium-137 exist in game animals of the southeastern United States. The highest levels, ranging from 250 to 152,940 picocuries per kilogram, have been found in muscle tissue of the Whitetail deer. Levels in Florida range from 10 to 100 times those encountered in Alabama. An important factor in the diet of these animals in Florida is the common gill mushroom, *Agaricaceae*. Examination of these fungi revealed cesium-137 levels higher by an order of magnitude than levels in vegetation. Similar concentrations of potassium-40 do not occur, indicating a selective effect.

Levels of cesium-137 range from less than 250 pCi/kg among wild animals found in the mountain regions of the southeastern United States to 152,940 pCi/kg among those of the lower coastal plains (1). Of all species investigated, Whitetail deer have the highest levels, particularly those from the Florida flatwoods. Levels among them are 10 to 100 times greater than deer of the same species from Alabama. Occurring in the winter months, November through January, the highest levels encountered were more than 300 times that of domestic livestock (2).

In Florida, in 1969, the mean level of cesium-137 in deer sampled was 19,615 pCi/kg wet weight with a range of 9,300 to 34,000 pCi/kg³ (seven animals sampled). This agrees closely with unpublished data of Dr. James H. Jenkins and Timothy J. Fendley of the University of Georgia, relative to 60 samples of deer meat collected in Florida.

In contrast, in Florida, in 1967, the mean level of cesium-137 in grain-fed beef was 214 pCi/kg (statewide average of 33 animals sampled) with a

range of 55 to 539 pCi/kg (3). Cattle, fed primarily on grass, averaged 4,000 pCi/kg with a range in lean meat of 290 to 12,500 pCi/kg (4).

The highest radionuclide concentration reported in meat is on the order of 10,000 pCi/kg. This level was calculated by Roessler et al. to result from an equilibrium concentration in grass of 10,000 pCi/kg dry weight, using a transfer coefficient (corresponds to fraction passing from gastrointestinal tract to blood) of 0.1 and assuming an intake of 10 kg of grass per day dry weight. In 1963-1964, Porter et al. reported the upper limit level of cesium-137 in pangola grass near Tampa to range from 3,700 to 9,600 pCi/kg dry weight (5).

Roessler et al. concluded that elevated levels of cesium-137 in domestic animal products appear to be due to the intake of elevated levels of the radionuclide with locally grown forages (6). Evidence suggests that an environmental mechanism is responsible for concentrating cesium-137 to an unusual degree in Florida since grain-fed animals do not show high levels. This type of feed is imported largely from other states. Since levels found in deer differ so markedly from domestic cattle on local forage, a food source of cesium-137 unlike local cattle forage would be expected.

On most Florida ranges, deer probably need between 5 and 80 pounds of feed per day, according to the Game and Fresh Water Fish Division, Florida Department of Natural Resources

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(7). Grass is not a significant part of their diet. It is eaten but in winter constitutes less than 1 percent of the diet. Contents of the stomachs of 423 deer, collected during the months of November to January (1953-1958), revealed that 85 percent of their diet consisted of oak acorns and leaves, palmetto berries, mushrooms, bamboo briar, deer's tongue, gallberry, titi, blueberry leaves, holly, Virginia willow, sweet bay, legumes, wicky, ferns, sumac, willow, elderberry, black haw, yellow jasmine, and blackberry leaves.

Food items found in deer rumen indicated that the diet consisted of 40.8 percent mast, principally acorns and palmetto berries; 37.6 percent woody plants; 11.4 percent herbaceous material; 9.2 percent mushrooms, and 1.0 percent grasses, pine needles, moss, Indian pipe, etc.

Materials and methods

Because of the elevated levels of cesium-137 in deer meat compared to domestic animals, it was decided to study the diet of deer to determine whether an item or items high enough in cesium-137 to support these body burdens could be demonstrated. An estimate of the levels of cesium-137 required in the deer diet was made utilizing the expression:

$$B = \sum_{i=1}^n f_i \frac{t}{0.693} (1 - e^{-0.693(tm/t)}) (e^{-0.693(td/t)}) \quad (1)$$

Where

- B = body burden of cesium-137 in pCi
- f = fraction of cesium-137 passing from gastrointestinal tract to blood (taken as 1).
- I = cesium-137 intake (pCi/day)
- t = effective half-life of cesium-137 in days
- tm = reporting period for intake values in days, and
- td = period between ith period and period of body burden estimation.

This expression was adopted from reference (1) and with suitable modification it can be calculated that the concentration of cesium-137

in food required to maintain a body burden of 20,000 pCi/kg would be 2,900 pCi/kg net weight assuming the body burden to be 0 when $t = 0$, a body weight in an animal of 100 pounds (about 40 kg), and a daily food intake of 20 pounds (about 8 kg). This calculation assumes that the transfer coefficient is 1.0. If the value for transfer coefficient utilized by Roessler et al. is adopted (0.1) the value would be 23,000 pCi/kg wet weight which is in good agreement with the value for grass by that group.

During 1968, several forms of vegetation were sampled in preoperational surveillance of the Turkey Point reactor site in Dade County. We found a mean value in vegetation of 143 pCi/kg wet weight with a range of 45 to 671 pCi/kg wet weight. This range is similar to that of samples collected from other locations and appears too low, by about two orders of magnitude, to support the body burdens found in deer.

We collected a single sample of unclassified gill mushrooms (Agaricaceae) and analyzed it by gamma spectroscopy. The cesium-137 level was 11,000 pCi/kg wet weight. Analysis of samples collected in wooded areas or from lawns, logs, and trees at randomly selected sites in Duval, Clay and Dixie Counties also showed elevated levels of cesium-137 (table 1). These distributions of values are consistent with other reports (8).

The highest levels of cesium-137 are associated with wooded areas having a heavy layer of decaying humus and the lowest levels are associated with grassy, treeless locations, such as lawns. Levels in mushrooms collected in wooded areas appear high enough to support the body burdens found in deer.

The means of cesium-137 levels from mushrooms in different habitats are significantly different at the 95-percent confidence level utilizing the "Student-t" distribution. Means of potassium-40 levels are not significantly different at the 95-percent confidence level.

When cesium-137 levels of other foods in the deer diet were compared, we found the mean to be an order of magnitude lower than that of mushrooms collected from wooded areas. Results are shown in table 2 of analysis of Sabal palmetto leaves collected in preoperational sampling from a nuclear power plant site in Citrus County during May-September 1969.

Table 1. Concentration of cesium-137 and potassium-40 in unclassified mushroom species (*Agaricomycetes*) and soil, Florida, August-October 1969

Sampling location	Sample	Fungus (pCi/kg wet weight)		Soil (pCi/kg wet weight)	
		Cesium-137	Potassium-40	Cesium-137	Potassium-40
Wooded areas (pine and oak).....	1	11,000	12,000		
	2	19,000	4,800		
	3	19,000	5,300		
	4	4,300	5,900	1,400	400
	5	15,000	3,000	300	140
	6	15,000	3,500	300	140
	7	9,700	2,800	380	240
	8	8,900	3,100	180	170
	9	20,000	2,300	400	1,600
	10	29,000	3,700	400	1,600
	11	25,000	3,700		
	12	18,000	2,300		
Mean.....		15,700	3,580	292	626
Range.....		4,300-29,000	2,300-5,900	100-400	140-1,600
Lawns (principally St. Augustine grass).....	1	280	3,800		
	2	220	3,800		
	3	250	4,800		
	4	200	4,600		
	5	140	900	520	ND
Mean.....		208	3,620		
Range.....		140-250	900-4,900		
Growing on logs, trees.....	1	1,100	6,400		
	2	1,200	5,900		
	3	1,300	2,800		
	4	2,600	650	500	ND
	5	4,600	1,100	400	1,600
Mean.....		2,040	3,250	430	
Range.....		1,100-4,600	650-6,400	400-500	

* Discarded as stranger.

ND, nondetectable, minimum detectable level—104 pCi/kg.

Table 2. Representative mean values for cesium-137 and potassium-40 levels in palmetto leaves—Crystal River, Citrus County, May-September 1969

Sampling location	Concentration (pCi/kg wet weight)			
	Palmetto leaves		Soil	
	Cesium-137	Potassium-40	Cesium-137	Potassium-40
01.....	148	5,100	130	ND
02.....	632	5,460	216	ND
03.....	345	2,740	466	ND
04.....	*3,040	3,660	402	ND
05.....	746	5,220	686	ND
06.....	*3,760	2,700	925	ND
06.....	130	5,640	50	ND
Mean.....	1,260	4,650	410	ND
Range.....	130-3,760	2,700-5,460	50-925	

* Pine wooded area.

ND, nondetectable, minimum detectable level—104 pCi/kg.

In table 3 are listed the means and ranges of cesium-137 in two grasses sampled during January to October 1969 in connection with pre-operational surveillance around a nuclear power plant in Dade County.

Ranges of potassium-40 concentrations in foods from various locations are compared in table 4.

Discussion

Levels of cesium-137 as high as 150,000 pCi/kg of muscle have been found in Whitetail deer from certain areas of Florida. A level of 2,300 to 28,000 pCi/kg wet weight in foods would be necessary to support mean body burdens of

**Table 3. Cesium-137 and potassium-40 levels in selected environmental vectors
Turkey Point, Dade County, 1969**

Vector		Concentration (pCi/kg wet weight)			
		Vegetation		Soil	
		Cesium-137	Potassium-40	Cesium-137	Potassium-40
Bermuda Grass..... (<i>Cynodon dactylon</i>)	Mean Range	190 60-360	4,357 2,600-7,200	401 180-670	ND
Strawgrass..... (<i>Eleocharis</i>)	Mean Range	377 130-400	3,425 2,000-4,300	213 70-310	ND

ND, nondetectable.

Table 4. A comparison of the ranges of potassium-40 concentrations from various Florida locations and vectors

Vector	Range of potassium-40 in vegetation (pCi/kg wet weight)	Range of potassium-40 in soil (pCi/kg wet weight)
Mushrooms from wooded areas..	2,300-5,000	140-1,600
Mushrooms on logs, trees.....	630-6,400	
Mushrooms on lawns.....	990-4,900	
Palmetto (Citrus County).....	2,700-6,460	530
Bermuda Grass (Dade County)...	2,600-7,200	ND
Strawgrass (Dade County).....	2,000-4,300	ND

ND, nondetectable.

20,000 pCi/kg if the ingestion period were confined to 6 months. We selected a 6-month ingestion period because mushrooms are not plentiful in north Florida during December to March. The fact that the highest levels of cesium-137 were found in deer during the early winter, and the lowest, in spring and early summer, would be consistent with seasonal appearance of mushrooms in north Florida. A lower intake during the winter months would result in lower body burdens in late winter and early spring.

The common gill mushroom is the only food sampled which had high enough cesium-137 levels to support the body burden found in deer. Ranges of reported levels of potassium-40 in all food and soil samples showed no significant variation. The value of the range of cesium-137 in mushrooms showed significant variation as related to habitat and between the highest levels and those encountered in other foods. It appears that high levels in mushrooms from wooded habitats constitute a true concentration of cesium-137 and not a variation in potassium levels. The

concentration is consistent with the report that a common soil fungus (*Trichoderma viride*) concentrates cesium-137 by a factor of 10.4 over the levels in the substrate regardless of the donor substrate (9).

Conclusion

Levels of cesium-137 in deer of certain areas of Florida exceed levels found in domestic cattle by one or two orders of magnitude. A food containing high levels appears to be the source of this body burden. Analysis of the common gill mushroom (*Agaricaceae*) from heavily wooded areas revealed levels as high as 29,000 pCi/kg wet weight and a mean value of 15,741 pCi/kg. This elevation over levels in soil occurs without a similar concentration of potassium-40 and is thought to constitute a true selective concentration of cesium-137. Other reported deer foods have not been analyzed, and mushrooms may contribute only a portion of the cesium-137 body burden to deer. No vegetation samples have been analyzed by the Florida Radiological Surveillance Network which would support the reported high body burdens in deer at reasonable food intake levels. Mushrooms also appear to be a useful indicator for cesium-137 in the environment and may provide a basis for the high levels reported in deer. Other environmental samples, such as seeds, nuts, and palmetto berries, should be studied to provide clarification of the cesium transport to deer.

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SECTION I. MILK AND FOOD

Milk Surveillance, June 1970

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Bureau of Radiological Health and the Bureau of Foods, Pesticides and Product Safety, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations

Canadian Milk Network (Radiation and Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that occur in, or are formed as a result of, nuclear fission become incorporated in milk (1). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (2) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostron-



Figure 1. Milk sampling networks in the Western Hemisphere

tium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variation, expressed in terms of 2-standard deviations (2σ), for these concentrations are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for the period, May 1963-March 1966 (3) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (4).

The most recent study was conducted in the period, July-September 1969, with 31 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 14 participated in the experiment.

The iodine-131 and cesium-137 results show much improvement over previous tests. Barium-140 results also look good which is encouraging, since this is the first time barium-140 was analyzed for this type of experiment. However, strontium-89 and strontium-90 analyses still need improvement (5). Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error due to disagreement among the independently obtained data.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding

of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methodologies, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A recent article (6) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analysis more often than once a month. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short time periods, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. A recent analysis (7) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or

sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analysis (3). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurement equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical errors or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (3). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1-5 pCi/liter for levels <50 pCi/liter; 5-10% for levels ≥50 pCi/liter
Strontium-90	1-2 pCi/liter for levels <20 pCi/liter; 4-10% for levels ≥20 pCi/liter

Iodine-131 } Cesium-137 } Barium-140 }	4-10 pCi/liter for levels <100 pCi/liter; 4-10% for levels ≥100 pCi/liter
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For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance to Federal agencies in the formulation of radiation standards.

Radiation Protection Guides (8, 9)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result due to exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 1 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (3).

In the absence of specific dietary data, one can use milk as the indicator food item for routine surveillance. Assuming a 1-liter per day intake of milk, one can utilize the graded approach of daily intake on the basis of radionuclide content in

Table 1. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Nuclide	Critical organ	RPG for individual in the general population (rad/a)	Guidance for suitable samples of exposed population groups ^a				
			RPG (rad/a)	Corresponding continuous daily intake (pCi/day)	Range I (pCi/day) ^b	Range II (pCi/day) ^b	Range III (pCi/day) ^b
Strontium-90	Bone	• 1.5	0.5	• 2,000	0-200	200-2,000	2,000-20,000
	Bone marrow	• .5	.17				
Strontium-90	Bone	• 1.5	.5	• 200	0-20	20-200	200-2,000
	Bone marrow	• .5	.17				
Iodine-131	Thyroid	1.5	.5	100	0-10	10-100	100-1,000
Cesium-137 ^c	Whole body	.5	.17	3,600	0-300	300-3,000	3,000-30,000

^a Suitable samples which represent the limiting conditions for this guidance are: strontium-90, strontium-90—general population; iodine-131—children 1 year of age; cesium-137—infants.

^b Based on an average intake of 1 liter of milk per day.

^c A dose of 1.5 rad/a to the bone is estimated to result in a dose of 0.5 rad/a to the bone marrow.

^d For strontium-90 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.

^e The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Protective Action Guides (10, 11)

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption

that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1 or 2-year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 2 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier (3). Also given in table 2 are milk concentrations for each of the radionuclides considered, in the absence of others, which if attained after an acute incident, would result in doses equivalent to the

Table 2. Protection Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-90	Bone marrow	10 in first yr; total dose not to exceed	3 in first yr; total dose not to exceed 5 ^{a,b}	• 1,110,000
Strontium-90	Bone marrow			• 51,000
Cesium-137	Whole body	15 ^{a,b}		• 720,000
Iodine-131	Thyroid	30	10	• 70,000

^a The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.

^b Total dose from strontium-90 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.

^c These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.

^d This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

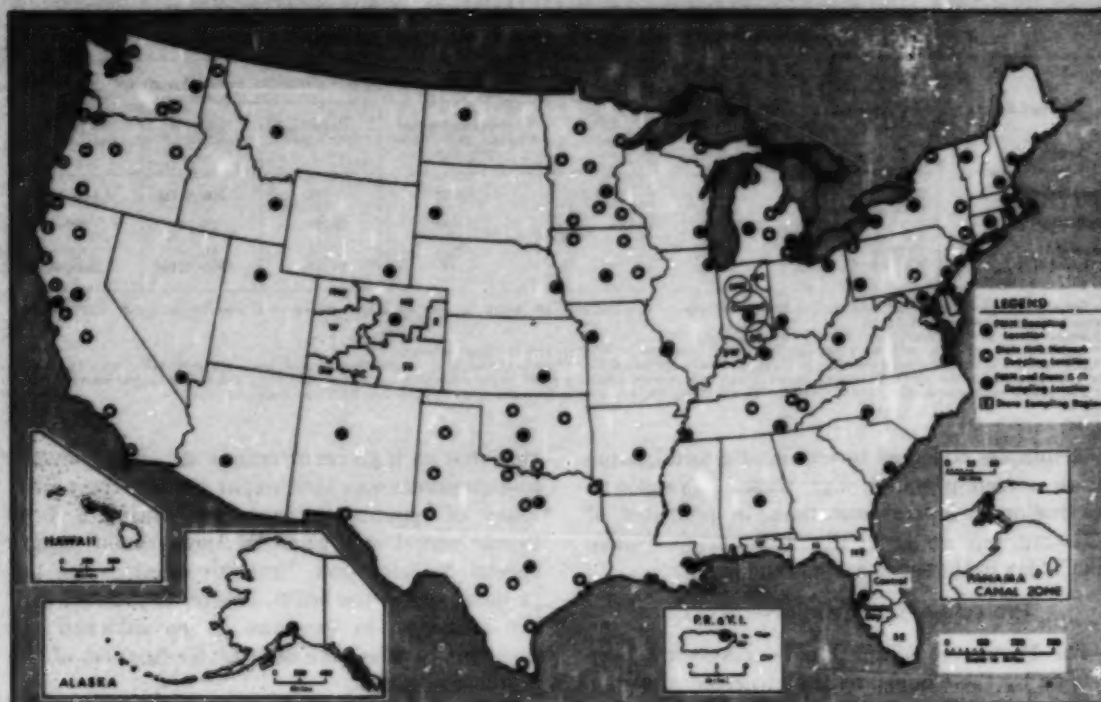


Figure 2. State and PMN milk sampling locations in the United States

appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the pasture-cow-milk-man pathway, as well as an estimate of the intake prior to reaching the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in retrospective manner.

Data reporting format

Table 3 presents the integrated results of the international, national, and State networks. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. (The relationship between the PMN stations and State stations is shown in figure 2.) The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using

the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 3, surveillance results are given for strontium-90, iodine-131, and cesium-137 for June 1970 and the 12-month period, July 1969 to June 1970. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 3 since levels at the great

Table 3. Concentration of radionuclides in milk for June 1970 and 12-month period, July 1969 through June 1970

Sampling location		Type of sample ^a	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average ^b	12-month average	Monthly average ^b	12-month average	Monthly average ^b	12-month average
UNITED STATES:								
Ala:	Montgomery	P	4	6	0 (4)	0	3 (4)	10
Alaska:	Palmer	P	6	5	0 (5)	0	3 (5)	4
Ark:	Farming	P	0	1	0 (4)	0	0 (4)	0
Ark:	Little Rock	P	16	14	0 (5)	0	18 (5)	18
Calif:	Sacramento	P	4	1	0 (4)	0	0 (4)	0
Calif:	San Francisco	P	4	2	0 (3)	0	0 (3)	0
Calif:	Del Norte	P	21	10	0	0	21	19
Calif:	France	P	2	2	0	0	0	6
Calif:	Humboldt	P	3	5	0	0	11	6
Calif:	Los Angeles	P	2	2	0	0	0	3
Calif:	Mendocino	P	3	3	0	0	0	3
Calif:	Sacramento	P	3	3	0	0	0	3
Calif:	San Diego	P	3	3	0	0	0	2
Calif:	Santa Clara	P	3	2	0	0	0	2
Calif:	Shasta	P	3	3	0	0	0	3
Calif:	Sonoma	P	4	3	0	0	0	3
Calif:	Denver	P	7	5	0 (4)	0	4 (4)	2
Calif:	West	R	(4)		NS	(4)	NS	4
Calif:	Northeast	R	(4)		(4)	(4)	(4)	(4)
Calif:	East	R	(4)		NS	(4)	NS	(4)
Calif:	Southwest	R	(4)		(4)	(4)	(4)	(4)
Calif:	South Central	R	(4)		NS	(4)	NS	NS
Calif:	Southwest	R	(4)		(4)	(4)	31	7
Conn:	Hartford	P	9	8	NS	(4)	NS	(4)
Conn:	Central	P	9	8	0 (4)	0	18 (4)	11
Del:	Wilmington	P	11	7	0 (4)	0	20 (4)	12
D.C.:	Washington	P	8	7	0 (4)	0	15 (4)	5
Fla:	Tampa	P	3	5	0 (4)	0	57 (4)	6
Fla:	West	R	14	11	0	0	38	24
Fla:	North	R	13	11	0	0	32	25
Fla:	Northeast	R	5	7	0	0	30	44
Fla:	Central	R	5	7	0	0	98	46
Fla:	Tampa Bay area	R	5	7	0	0	54	48
Fla:	Southeast	R	6	8	0	0	83	73
Ga:	Atlanta	P	12	10	0 (4)	0	18 (4)	18
Hawaii:	Honolulu	P	3	2	0 (5)	0	0 (5)	0
Idaho:	Idaho Falls	P	4	5	0 (4)	0	9 (4)	3
Ill:	Chicago	P	9	8	0 (5)	0	14 (5)	8
Ind:	Indianapolis	P	9	8	0 (5)	0	8 (5)	5
Ind:	Northeast	P	13	10	0	1	10	14
Ind:	Southeast	P	17	11	0	0	0	11
Ind:	Central	P	14	10	0	0	10	0
Ind:	Southwest	P	19	11	0	0	10	12
Iowa:	Northwest	P	16	11	0	0	10	16
Iowa:	Des Moines	P	6	6	0 (4)	0	3 (4)	2
Iowa:	Iowa City	P	9	8	0	0	22	10
Iowa:	Des Moines	P	9(4)	7	0 (5)	0	14	5
Iowa:	Spencer	P	5	5	NA	0	NA	5
Kans:	Fredericksburg	P	NS	NS	NS	NS	NS	NS
Kans:	Wichita	P	8	8	0 (5)	0	3 (5)	0
Ky:	Louisville	P	14	9	0 (5)	0	11 (5)	4
La:	New Orleans	P	16	15	0 (4)	0	23 (4)	18
Maine:	Portland	P	11	11	0 (4)	0	28 (4)	22
Md:	Baltimore	P	10	8	0 (5)	0	10 (5)	7
Mass:	Boston	P	13	11	0 (5)	0	28 (5)	21
Mich:	Detroit	P	7	8	0 (5)	0	11 (5)	8
Mich:	Grand Rapids	P	11	9	0 (5)	0	15 (5)	11
Mich:	Bay City	P	NS	7	NS	(4)	NS	9
Mich:	Charlevoix	P	14	12	(4) (4)	(4)	20 (4)	18
Mich:	Detroit	P	7	7	(4) (5)	(4)	3 (5)	7
Mich:	Grand Rapids	P	11	9	(4) (5)	(4)	11 (5)	11
Mich:	Lansing	P	10	9	(4) (2)	(4)	21 (2)	16
Mich:	Marquette	P	15	13	(4) (3)	1	24 (3)	24
Mich:	Monroe	P	8	6	(4) (2)	(4)	0 (2)	2
Mich:	South Haven	P	NA	NA	(4) (5)	(4)	7 (5)	6
Minn:	Minneapolis	P	12	9	0 (5)	0	13 (5)	7
Minn:	Benidji	P	5	18	0	0	14	24
Minn:	Mankato	P	4	6	0	0	0	0
Minn:	Rochester	P	7	8	0	0	19	11
Minn:	Duluth	P	20	17	0	0	34	26
Minn:	Worthington	P	4	6	0	0	0	0
Minn:	Minneapolis	P	11	10	0	0	21	13
Minn:	Fergus Falls	P	3	8	0	0	20	13
Minn:	Little Falls	P	3	9	0	0	20	13
Miss:	Jackson	P	13	12	0 (5)	0	15 (5)	12
Mo:	Kansas City	P	10	8	0 (4)	0	8 (4)	2
Mo:	St. Louis	P	11	8	0 (4)	0	7 (4)	2
Mont:	Helena	P	5	5	0 (4)	0	6 (4)	5
Neb:	Omaha	P	8	6	0 (4)	0	0 (4)	1
Nev:	Las Vegas	P	0	1	0 (5)	0	0 (5)	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for June 1970 and 12-month period, July 1969 through June 1970—Continued

Sampling location		Type of sample ^a	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average ^b	12-month average	Monthly average ^b	12-month average	Monthly average ^b	12-month average
UNITED STATES—Continued								
N.H.:	Manchester ^c	P	10	8	0 (5)	0	10 (3)	18
N.J.:	Trenton ^c	P	8	8	0 (5)	0	17 (5)	6
N. Mex.:	Albuquerque ^c	P	4	3	0 (4)	0	0 (4)	0
N.Y.:	Buffalo ^c	P	9	7	0 (4)	0	10 (4)	7
	New York City ^c	P	13	10	0 (5)	0	18 (5)	13
	Syracuse ^c	P	8	7	0 (4)	0	6 (4)	9
	Albany ^c	P	5	4	0 (3)	0	0 (3)	0
	Buffalo ^c	P	(^d)	(^d)	0	0	0	0
	Massena ^c	P	7	6	0 (2)	0	26 (2)	0
	Newburg ^c	P	13	7	0 (3)	0	0 (3)	0
	New York City ^c	P	3	4	0 (2)	0	0 (2)	0
	Syracuse ^c	P	6	6	0 (4)	0	0 (4)	0
N.C.:	Charlotte ^c	P	10	11	0 (5)	0	15 (5)	12
N. Dak.:	Minot ^c	P	2	9	0 (5)	0	14 (5)	15
Ohio:	Cincinnati ^c	P	9	8	0 (4)	0	10 (4)	4
	Cleveland ^c	P	2	9	0 (4)	0	11 (4)	5
Okla.:	Oklahoma City ^c	P	7	6	0 (5)	0	12 (5)	8
	Oklahoma City ^c	P	NS	NS	NS	NS	NS	NS
	Enid ^c	P	NS	NS	NS	NS	NS	NS
	Tulsa ^c	P	NS	NS	NS	NS	NS	NS
	Lawton ^c	P	NS	NS	NS	NS	NS	NS
	Ardmore ^c	P	NS	NS	NS	NS	NS	NS
Oreg.:	Portland ^c	P	8	6	0 (4)	0	5 (4)	6
	Baker ^c	P	NA	3	(^d)	(^d)	(^d)	(^d)
	Coco Bay ^c	P	NA	5	(^d)	(^d)	24	12
	Eugene ^c	P	NA	2	(^d)	(^d)	(^d)	6
	Medford ^c	P	NA	2	(^d)	(^d)	16	8
	Portland composite ^c	P	NA	4	(^d)	(^d)	11	7
	Portland local ^c	P	NA	5	(^d)	(^d)	10	8
	Redmond ^c	P	NA	2	(^d)	(^d)	(^d)	3
	Tillamook ^c	P	NA	6	(^d)	(^d)	(^d)	13
Pa.:	Philadelphia ^c	P	9	9	0 (4)	0	11 (4)	5
	Pittsburgh ^c	P	11	11	0 (5)	0	18 (5)	9
	Dauphin ^c	P	9	7	0	3	13	11
	Erie ^c	P	19	11	0	6	25	25
	Philadelphia ^c	P	12	8	0	4	18	12
	Pittsburgh ^c	P	20	12	0	3	24	19
R.I.:	Providence ^c	P	12	9	0 (5)	0	25 (5)	15
S.C.:	Charleston ^c	P	13	10	0 (5)	0	17 (5)	22
S.Dak.:	Rapid City ^c	P	10	8	0 (5)	0	10 (5)	4
Tenn.:	Chattanooga ^c	P	11	10	0 (5)	0	14 (5)	12
	Memphis ^c	P	10	9	0 (4)	0	11 (4)	5
	Chattanooga ^c	P	11	12	3 (4)	0	18 (4)	13
	Clinton ^c	P	16	14	0	0	22	12
	Knoxville ^c	P	8	9	0 (2)	0	14 (2)	6
	Nashville ^c	P	8	8	0	0	13	7
	Fayetteville ^c	P	18	13	0 (2)	0	21 (2)	16
Tex.:	Austin ^c	P	3	2	0 (3)	0	9 (3)	3
	Dallas ^c	P	9	6	0 (4)	0	11 (4)	7
	Amarillo ^c	R	NS	NS	NS	NS	NS	NS
	Corpus Christi ^c	R	NS	NS	NS	NS	NS	NS
	El Paso ^c	R	NS	NS	NS	NS	NS	NS
	Fort Worth ^c	R	NS	NS	NS	NS	NS	NS
	Harlingen ^c	R	NS	NS	NS	NS	NS	NS
	Houston ^c	R	NS	NS	NS	NS	NS	NS
	Lubbock ^c	R	NS	NS	NS	NS	NS	NS
	Midland ^c	R	NS	NS	NS	NS	NS	NS
	San Antonio ^c	R	NS	NS	NS	NS	NS	NS
	Texasboro ^c	R	NS	NS	NS	NS	NS	NS
	Uvalde ^c	R	NS	NS	NS	NS	NS	NS
	Wichita Falls ^c	R	NS	NS	NS	NS	NS	NS
Utah:	Salt Lake City ^c	P	4	4	0 (4)	0	10 (4)	3
Vt.:	Burlington ^c	P	10	8	0 (4)	0	17 (4)	12
Va.:	Norfolk ^c	P	10	10	0 (4)	0	14 (4)	8
Wash.:	Seattle ^c	P	5	6	0 (4)	0	4 (4)	6
	Spokane ^c	P	5	6	0 (2)	0	2 (2)	2
	Benton County ^c	R	NS	0	NS	0	NS	7
	Franklin County ^c	R	0	2	0	0	0	3
	Sandpoint, Idaho ^c	R	9	10	0	0	23	25
	Skagit County ^c	R	7	6	0	0	6	12
W. Va.:	Charleston ^c	P	7	8	0 (4)	0	6 (4)	5
Wisc.:	Milwaukee ^c	P	7	7	0 (4)	0	3 (4)	9
Wyo.:	Laramie ^c	P	4	5	0 (2)	0	0 (2)	2
CANADA:								
Alberta:	Calgary ^c	P	5	8	(^d)		15	18
	Edmonton ^c	P	7	7	(^d)		NA	
British Columbia:	Vancouver ^c	P	12	10	(^d)		37	30
Manitoba:	Winnipeg ^c	P	4	7	(^d)		24	25

See footnotes at end of table.

Table 3. Concentrations of radionuclides in milk for June 1970 and 12-month period, July 1969 through June 1970—Continued

Sampling location		Type of sample ^a	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average ^b	12-month average	Monthly average ^b	12-month average	Monthly average ^b	12-month average
CANADA—Continued								
New Brunswick:	Frederickton.....	P	10	13	(4)		18	10
Newfoundland:	St. John's.....	P	14	17	(4)		40	36
Nova Scotia:	Halifax.....	P	10	10	(4)		16	20
Ontario:	Ft. William.....	P	13	14	(4)		21	20
	Ottawa.....	P	4	7	(4)		13	13
	Sault Ste. Marie.....	P	13	14	(4)		43	30
	Toronto.....	P	3	4	(4)		8	10
	Windsor.....	P	5	8	(4)		13	10
Quebec:	Montreal.....	P	6	8	(4)		16	17
	Quebec.....	P	8	10	(4)		36	36
Saskatchewan:	Regina.....	P	6	7	(4)		15	14
	Saskatoon.....	P	12	8	(4)		16	11
CENTRAL AND SOUTH AMERICA:								
Colombia:	Bogota.....	P	2	2	0	0	0	3
Chile:	Santiago.....	P	0	0	0	0	0	2
Ecuador:	Guayaquil.....	P	2	0	0	0	0	0
Jamaica:	Montego Bay.....	P	9	5	0	5	155	84
Venezuela:	Caracas.....	P	0	2	0	0	0	0
Canal Zone:	Cristobal.....	P	2	1	0 (5)	0	12 (5)	10
Puerto Rico:	San Juan ^c	P	4	3	0 (3)	0	9 (3)	7
PMN Network average ^d			8	7	0	0	11	8

^a P, pasteurized milk.

R, raw milk.

^b When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

^c PHS Pasteurized Milk Network station. All other sampling locations are part of the State or national network.

^d Radionuclide analysis not routinely performed.

^e The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter
Michigan—14 pCi/liter
Oregon—15 pCi/liter

Cesium-137: Colorado—25 pCi/liter
New York—20 pCi/liter
Oregon—15 pCi/liter

Strontium-90: New York—3 pCi/liter

^f This entry gives the average radionuclide concentrations for the PHS Pasteurized Milk Network stations denoted by footnote ^c.

NA, no analysis.
NS, no sample.

majority of the stations for June 1970 were below the respective practical reporting levels. Table 4 gives monthly averages for those stations at which strontium-90 was detected.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (see table 1), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 21 pCi/liter in the United States for the month of June 1970; and the highest 12-month average was 19 pCi/liter (Del Norte, Calif.), representing

Table 4. Strontium-90 in milk, June 1970

Sampling location	Radionuclide concentration (pCi/liter)
Calif., Del Norte (State)	12
Iowa, Des Moines (PMN)	6
La., New Orleans (PMN)	11
Minn., Minneapolis (PMN)	8
Mo., St. Louis (PMN)	6
N.Y., Albany (State)	3 (2 samples)
Massena (State)	7 (2 samples)
Syracuse (State)	6
Okla., Oklahoma City (PMN)	7
Tenn., Fayetteville (State)	6
Tex., Dallas (PMN)	9
Wash., Seattle (PMN)	7

9.5 percent of the Federal Radiation Council radiation protection guide (table 1). Cesium-137 monthly averages ranged from 0 to 98 pCi/liter in the United States for the month of June 1970; and the highest 12-month average was 73 pCi/liter (southeast Florida), representing 2.0 percent

of the value presented in this report using the recommendations given in the *Federal Radiation Council* reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (12) and Jamaica. Iodine-131 results for individual samples were all

below the practical reporting level.

The Canadian Department of National Health and Welfare, as of May 1970, have changed their analysis pattern. Monthly samples will be collected and composited for quarterly analysis of strontium-90.

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Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiological Health Section
Division of Air, Occupational and
Radiation Hygiene
Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational
Health Section
Department of Health and
Rehabilitative Services
Florida State Board of Health

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National
Health and Welfare

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Health
Division of Environmental Health Services
New York State Department of Health

Division of Occupational and Radiological
Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows.

<u>Program</u>	<u>Period reported</u>	<u>Issue</u>
California Diet Study	October-December 1968 and January-March 1969	May 1970
Connecticut Diet Study	July-December 1968 and January-June 1969	February 1970
Radionuclides in Institutional Diet Samples, <i>PHS</i>	October-December 1969 and annual summary 1969	August 1970
Strontium-90 in Tri-City Diets, <i>HASL</i>	June-December 1969	June 1970

SECTION II. WATER

The Public Health Service, the Federal Water Quality Administration, and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (1). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (2-4), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total

intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence¹ of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

¹ Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

<u>Water sampling program</u>	<u>Period reported</u>	<u>Issue</u>
California	July-December 1968	August 1970
Kansas	January-December 1969	September 1970
Minnesota	January-June 1969	January 1970
New York	January-June 1969	June 1970
North Carolina	January-December 1967	May 1969
Radiostrontium in Tap Water, HASL	January-December 1969	July 1970
Tritium Network	July-December 1969	July 1970
Washington	July 1967-June 1968	June 1969

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically

to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*:

Network
Tritium in Precipitation

Period
July-December 1969

Issue
July 1970

1. Radiation Alert Network June 1970

National Air Pollution Control Administration
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate National Air Pollution Control Administration officials by

mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Division of Air Quality Emission Data, NAPCA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during June 1970. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting stations except the Denver, Colo., station which reported 23 pCi/m³ on June 2, 1970. The 29-hour field reading had decreased to 5 pCi/m³. This sample was analyzed at NERHL for specific nuclides. No unusual radioactivity above background was detected on this sample at the laboratory.



Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, June 1970

Station location		Air surveillance			Last profile in RHD&R	Precipitation					
		Number of samples	Gross beta radioactivity (pCi/m ³)			Number of samples	Total depth (mm)	Field estimation of deposition			
			Maximum	Minimum				Average ^a	Number of samples	Depth (mm)	Total deposition (mCi/m ²)
Ala:	Montgomery	22	11	0	3	Oct 70	5	175	5	175	80
Alaska:	Adak	(^b)				Oct 70	(^c)				
	Anchorage	12	0	0	0	Aug 69	(^c)				
	Attu Island	2	1	0	0	Mar 69	(^c)				
	Fairbanks	20	1	0	0	Sept 69	9	36	9	36	19
	Juneau	6	3	1	2	Aug 70	2	21	2	21	3
	Kodiak	2	0	0	1	Sept 70	(^c)				
	Nome	15	3	0	0	May 69	(^c)				
	Point Barrow	10	0	0	0	Apr 69	(^c)				
	St. Paul Island	(^b)				June 69	(^c)				
Aris:	Phoenix	13	6	2	3	Aug 70	(^c)				
Ark:	Little Rock	13	3	1	2	Aug 69	(^c)				
Calif:	Berkeley	21	1	0	0	Sept 70	1	14	1	14	1
	Los Angeles	21	2	1	1	May 69	(^c)				
C.E:	Ancon	17	0	0	0	Sept 70	(^c)				
Colo:	Denver	21	23	2	7	Sept 70	7	78	(^d)	4	44
Conn:	Hartford	22	2	0	1	Sept 69	3	67			5
Del:	Dover	21	1	0	1	July 69	(^c)				
D.C:	Washington	26	2	0	1	Apr 69	(^c)				
Fla:	Jacksonville	22	2	0	1	Aug 69	7	105	7	105	32
	Miami	17	3	0	0	Sept 69	9	135	135	9	0
Ga:	Atlanta	21	2	1	1	June 69	2	138	2	153	67
Guam:	Agaña	(^b)				July 69	(^c)				
Hawaii:	Honolulu	23	1	0	0	Mar 69	1	3	(^d)		
Idaho:	Boise	21	4	1	2	Mar 69	4	49	4	49	3
Ill:	Springfield	12	3	0	1	Apr 69	(^c)				
Ind:	Indianapolis	(^b)				June 69	(^c)				
Iowa:	Iowa City	13	3	1	1	Sept 70	3	127	3	127	13
Kans:	Topeka	22	4	0	2	Aug 69	11	185	11	185	0
Ky:	Frankfort	14	4	0	2	Apr 69	(^c)				
La:	New Orleans	21	1	0	0	Apr 69	4	136	(^d)		
Maine:	Augusta	22	8	0	2	Aug 70	3	93	3	96	0
Md:	Baltimore	22	2	0	1	Sept 69	7	63	7	63	15
	Rockville	14	2	0	1	Mar 69	(^c)				
Mass:	Lawrence	22	3	0	1	Sept 70	4	117	4	117	4
	Winchester	21	3	0	1	Oct 70	3	108	3	108	0
Mich:	Lansing	20	2	0	1	Mar 69	7	85	7	85	11
Minn:	Minneapolis	21	3	0	1	July 69	5	72	5	72	25
Miss:	Jackson	15	2	0	1	Aug 70	4	193	4	193	22
Mo:	Jefferson City	21	3	0	1	June 69	9	173	9	173	1
Mont:	Helena	14	3	1	1	Oct 70	2	6	2	6	0
Nebr:	Lincoln	17	6	1	3	June 69	4	56	4	56	19
Nev:	Las Vegas	21	3	1	2	Sept 69	(^c)				
N.H:	Concord	(^b)				Apr 69	(^c)				
N.J:	Trenton	20	2	0	1	Aug 70	10	105	10	105	10
N. Mex:	Santa Fe	17	3	0	1	Oct 70	3	6	3	6	1
N.Y:	Albany	16	2	0	1	June 69	2	34	2	34	11
	Buffalo	21	3	1	1	Sept 70	(^c)				
	New York City	(^b)				Oct 70	(^c)				
N.C:	Gastonia	15	11	1	5	Sept 70	1	15	(^d)	7	111
N. Dak:	Bismarck	21	4	1	2	Apr 69	7	111			4
Ohio:	Cincinnati	(^b)				July 69	(^c)				
	Columbus	5	4	1	3	Aug 70	(^c)				
	Painesville	21	4	0	2	Sept 69	9	73	9	73	17
Okla:	Oklahoma City	8	3	1	2	Mar 69	1	9	1	9	0
	Ponca City	21	4	1	2	Sept 69	8	65	8	65	1
Oreg:	Portland	21	2	0	1	June 69	4	13	4	13	2
Pa:	Harrisburg	16	2	0	1	June 69	2	41	2	41	11
P.R:	San Juan	(^b)				Aug 70	(^c)				
R.I:	Providence	21	2	0	1	Mar 69	3	39	3	39	4
S.C:	Columbia	16	3	0	1	Oct 70	3	41	3	41	0
S. Dak:	Pierre	7	7	2	4	Aug 70	(^c)				
Tenn:	Nashville	22	3	0	1	Mar 69	7	119	7	119	6
Tex:	Austin	15	6	1	3	July 69	(^c)				
	El Paso	(^b)				Apr 69	(^c)				
Utah:	Salt Lake City	30	2	0	1	May 69	6	30	6	30	0
Vt:	Barre	21	4	0	2	Aug 69	6	90	6	90	13
Va:	Richmond	22	2	0	1	Aug 69	3	30	3	30	4
Wash:	Seattle	20	1	0	0	Aug 69	2	9	(^d)		
	Spokane	21	2	0	1	July 69	(^c)				
W. Va:	Charleston	21	4	1	2	Oct 70	7	51	7	51	10
Wisc:	Madison	22	3	0	1	Oct 70	7	120	7	120	19
Wyo:	Chryenne	22	8	0	3	Aug 69	4	67	4	67	9
Network summary		1,142	23	0	1		6	86	3	79	12

^a The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.^b No report received. (Air samples received without field estimate data are not considered by the data program.)^c No precipitation sample collected.^d This station is part of the plutonium in precipitation network. No gross beta measurements are done.^e Samples were collected but no field estimates were received.

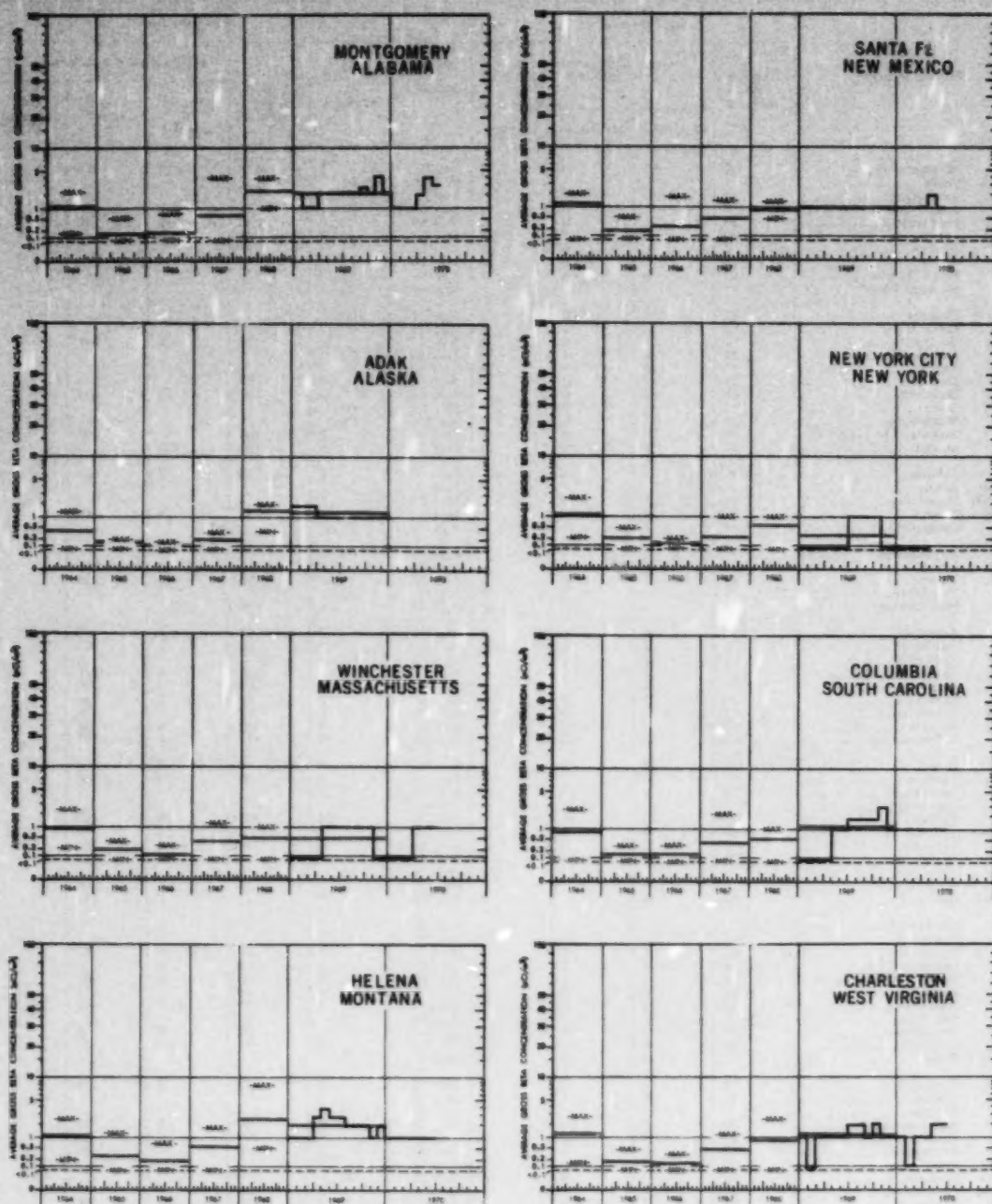


Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1964–June 1970

2. Canadian Air and Precipitation Monitoring Program¹, June 1970

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (1-5).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health and Data Reports*.

Surface air and precipitation data for June 1970 are presented in table 2.

¹ Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, June 1970

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m ³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m ²)
Calgary.....	30	1.0	0.2	0.6	31	4.9
Coral Harbour.....	29	.3	.0	.1	30	1.0
Edmonton.....	30	.7	.0	.4	124	14.9
Ft. Churchill.....	30	.5	.0	.2	240	3.3
Fredericton.....	30	.7	.0	.3	111	10.6
Goose Bay.....	30	.6	.0	.2	42	4.3
Halifax.....	29	.6	.0	.2	78	8.9
Inuvik.....	30	.5	.0	.2	92	2.5
Montreal.....	30	.8	.1	.4	236	11.4
Moosonee.....	30	.6	.1	.3	113	8.8
Ottawa.....	30	.7	.0	.4	66	1.8
Quebec.....	30	.6	.0	.3	146	13.2
Regina.....	30	.9	.0	.4	135	10.3
Resolute.....	29	.3	.0	.1	24	.4
St. John's, Nfld.....	29	.4	.0	.2	46	3.5
Saskatoon.....	30	.8	.1	.4	100	18.7
Sault Ste. Marie.....	29	1.0	.1	.4	52	3.1
Thunder Bay.....	29	.7	.1	.3	166	7.9
Toronto.....	30	1.0	.1	.5	207	7.7
Vancouver.....	23	.6	.1	.3	122	4.7
Whitehorse.....	30	.5	.0	.2	60	.9
Windsor.....	30	1.0	.1	.4	34	2.3
Winnipeg.....	21	.8	.2	.4	225	11.3
Yellowknife.....	30	.7	.1	.3	242	3.7
Network summary.....	698	1.0	0.0	0.3	119	6.7



Figure 3. Canadian air and precipitation sampling stations

**3. Mexican Air Monitoring Program
January-June 1970**

*National Commission of Nuclear Energy
México, D. F.*

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry

Department of the University of Mérida, the Instituto de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency, 6- by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron daughters. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of five samples per month was needed to get a reliable average radioactivity concentration at each station (6).

The maximum, minimum, and average beta radioactivity in surface air during January through June 1970 are presented in tables 3 through 8.



Figure 4. Mexican air sampling locations

Table 3. Mexican gross beta radioactivity of airborne particulates, January 1970

Station	Number of samples	Gross beta radioactivity (pCi/m ³)		
		Maximum	Minimum	Average ^a
Acapulco.....	NS			
Chihuahua.....	8	0.29	0.12	0.18
Ciudad Juarez.....	NS			
Ensenada.....	NS			
Guadalajara.....	NS			
Guaymas.....	NS			
La Paz.....	17	.10	.09	.12
Matamoros.....	NS			
Mazatlán.....	NS			
Mérida.....	2	.14	.09	
México, D.F.....	8	.23	.12	.15
Nuevo Laredo.....	7	.16	.06	.11
San Luis Potosí.....	NS			
Tampico.....	NS			
Torreón.....	14	.34	.11	.23
Veracruz.....	NS			

^a Average not calculated for less than 5 samples.
NS, no sample, station temporarily shutdown.

Table 4. Mexican gross beta radioactivity of airborne particulates, February 1970

Station	Number of samples	Gross beta radioactivity (pCi/m ³)		
		Maximum	Minimum	Average
Acapulco.....	NS			
Chihuahua.....	8	0.38	0.11	0.21
Ciudad Juarez.....	NS			
Ensenada.....	7	.24	.05	.13
Guadalajara.....	NS			
Guaymas.....	NS			
La Paz.....	13	.40	.11	.22
Matamoros.....	NS			
Mazatlán.....	NS			
Mérida.....	NS			
México, D.F.....	7	.23	<.03	.09
Nuevo Laredo.....	NS			
San Luis Potosí.....	NS			
Tampico.....	NS			
Torreón.....	NS			
Veracruz.....	14	.23	.06	.12

NS, no sample, station temporarily shutdown.

Table 5. Mexican gross beta radioactivity of airborne particulates, March 1970

Station	Number of samples	Gross beta radioactivity (pCi/m ³)		
		Maximum	Minimum	Average ^a
Acapulco.....	NS			
Chihuahua.....	NS			
Ciudad Juarez.....	6	0.29	0.08	0.16
Ensenada.....	6	.21	.13	.16
Guadalajara.....	NS			
Guaymas.....	NS			
La Paz.....	2	.28	.10	
Matamoros.....	NS			
Mazatlán.....	NS			
Mérida.....	14	.35	.12	.22
México, D.F.....	NS			
Nuevo Laredo.....	NS			
San Luis Potosí.....	NS			
Tampico.....	NS			
Torreón.....	15	.39	.07	.21
Veracruz.....	3	.17	.09	

^a Average not calculated for less than 5 samples.
NS, no sample, station temporarily shutdown.

Table 6. Mexican gross beta radioactivity of airborne particulates, April 1970

Station	Number of samples	Gross beta radioactivity (pCi/m ³)		
		Maximum	Minimum	Average ^a
Acapulco.....	NS			
Chihuahua.....	NS			
Ciudad Juarez.....	NS			
Ensenada.....	NS			
Guadalajara.....	NS			
Guaymas.....	NS			
La Paz.....	4	0.61	0.42	0.45
Matamoros.....	NS			
Mazatlán.....	NS			
Mérida.....	2	.68	.37	
México, D.F.....	NS			
Nuevo Laredo.....	NS			
San Luis Potosí.....	NS			
Tampico.....	NS			
Torreón.....	7	.90	.34	.57
Veracruz.....	6	.92	.28	.49

^a Average not calculated for less than 5 samples.
NS, no sample, station temporarily shutdown.

Table 7. Mexican gross beta radioactivity of airborne particulates, May 1970

Station	Number of samples	Gross beta radioactivity (pCi/m ³)		
		Maximum	Minimum	Average ^a
Acapulco.....	NS			
Chihuahua.....	NS			
Ciudad Juarez.....	11	0.87	0.17	0.61
Ensenada.....	NS			
Guadalajara.....	NS			
Guaymas.....	NS			
La Paz.....	2	.63	.02	
Matamoros.....	NS			
Mazatlán.....	NS			
Mérida.....	1	.51		
México, D.F.....	NS			
Nuevo Laredo.....	NS			
San Luis Potosí.....	NS			
Tampico.....	NS			
Torreón.....	NS			
Veracruz.....	1	.12		

^a Average not calculated for less than 5 samples.
NS, no sample, station temporarily shutdown.

Table 8. Mexican gross beta radioactivity of airborne particulates, June 1970

Station	Number of samples	Gross beta radioactivity (pCi/m ³)		
		Maximum	Minimum	Average ^a
Acapulco.....	NS			
Chihuahua.....	10	0.66	0.06	0.42
Ciudad Juarez.....	NS			
Ensenada.....	NS			
Guadalajara.....	NS			
Guaymas.....	NS			
La Paz.....	NS			
Matamoros.....	NS			
Mazatlán.....	NS			
Mérida.....	8	.70	.24	.38
México, D.F.....	NS			
Nuevo Laredo.....	NS			
San Luis Potosí.....	NS			
Tampico.....	NS			
Torreón.....	6	.43	.08	.22
Veracruz.....	NS			

NS, no sample, station temporarily shutdown.

4. Pan American Air Sampling Program June 1970

*Pan American Health Organization and
U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the January 1968 issue of *Radiological Health Data and Reports*. The June 1970 air monitoring results from the participating countries are given in table 9.

The higher value reported for LaPaz, Bolivia, on June 30 is attributed to recent foreign testing.



Figure 5. Pan American Air Sampling Program stations

Table 9. Summary of gross beta radioactivity in Pan American surface air, June 1970

Station location	Number of samples	Gross beta radioactivity (pCi/m ³)		
		Maximum	Minimum	Average*
Argentina: Buenos Aires	15	0.57	0.01	0.10
Bolivia: La Paz	15	14.7	.14	2.42
Chile: Santiago	20	.60	.05	.28
Colombia: Bogota	21	.74	.01	.17
Ecuador: Cuenca	NS			
Guayaquil	21	.76	.01	.32
Quito	NS			
Guyana: Georgetown	14	.33	.02	.15
Jamaica: Kingston	NS			
Peru: Lima	24	.95	.05	.35
Venezuela: Caracas	17	.74	.01	.24
West Indies: Trinidad	NS			
Pan American summary	156	14.7	0.01	0.45

* The monthly average is calculated by weighting the individual sample with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
NS, no sample.

Subsequent samples from this and other stations collected early in the month of July also reflect the increase. Gamma analysis of the filters indicate that the radioactivity is due primarily to barium-lanthanum-140.

5. Plutonium in Airborne Particulates April-December 1969

*Bureau of Radiological Health
U.S. Public Health Service*

The Radiation Alert Network (RAN) of the Bureau of Radiological Health, Public Health Service, routinely analyzes airborne particulate samples from 11 selected RAN stations for plutonium. The plutonium analyses were initiated in November 1965 and the results through March 1969 have been previously reported (7-19).

One-half of each individual air filter from the selected stations is sent to the Northeastern Radiological Health Laboratory, Winchester, Mass. The laboratory analyzes a composite of these samples for each station on a quarterly basis. During this period, however, the samples from Denver and Gastonia were composited and analyzed on a monthly basis and an arithmetical average reported for the quarter.

The results for April through December 1969 are presented in table 10. ND (nondetectable) has been used to indicate samples containing

Table 10. Plutonium in airborne particulates for April-December 1969

1969	Anchorage	Phoenix	Denver	Honolulu	New Orleans	Rockville	Buffalo	Gastonia ^a	Pierre	Austin	Seattle
Plutonium-238											
(fCi/m ³)											
April-June	0.012	0.040	0.080	0.012	0.026	0.018	0.027	0.019	0.020	0.023	0.012
July-September	.008	.006	.015	.004	.009	.007	.012	.006	.012	.009	.006
October-December	.005	.008	.006	.003	.004	.006	.003	.003	.007	.013	.002
Plutonium-239											
(fCi/m ³)											
April-June	.036	.240	.108	.041	.089	.074	.077	.050	.110	.080	.048
July-September	.034	.061	.064	.025	.060	.062	.073	.038	.043	.050	.034
October-December	.016	.057	.035	.019	.027	.021	.022	.016	.066	.040	.014
²³⁹Pu/²³⁸Pu											
April-June	3.00	4.90	3.60	3.42	3.42	4.11	2.85	2.63	5.50	3.87	4.00
July-September	4.25	10.17	4.27	6.25	7.50	8.86	6.08	6.33	3.7 ^a	5.58	5.67
October-December	3.20	7.13	5.83	6.33	6.75	3.50	7.33	5.33	9.43	3.08	7.00

^a Average of three individual monthly results.

plutonium-238 or plutonium-239 less than or equal to the appropriate minimum detectable activities (0.020 pCi and 0.015 pCi per sample for plutonium-238 and plutonium-239, respectively). The volume of air sampled varies, generally ranging from 20,000 to 30,000 cubic meters of air per month.

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Surface Air Sampling Program - 80th Meridian Network January-December 1966¹

*Health and Safety Laboratory
Atomic Energy Commission*

The Health and Safety Laboratory began its Surface Air Sampling Program in January 1963, as a continuation of the 80th Meridian Program conducted by the U.S. Naval Research Laboratory. The objectives of this program are to determine the concentrations of radioactivity in surface air in both hemispheres as a function of latitude and season, and to interpret these data in terms of the dominant meteorological and physical processes which are operative.

The basic network consists of a line of sites approximately along the 80th Meridian extending from about 76° N to 63° S latitudes (figure 1). Since 1963, a number of sites have been added to investigate the possible effects of longitude, elevation and proximity to coastlines; and in late 1965, samplers were placed on four Atlantic Ocean weather ships to extend the surface air study over the marine environment. The Environmental Science Services Administration, Department of Commerce, maintains a collection site at the Amundson Scott Station in Antarctica. The air filter samples from this site are also included in the HASL program.

Sampling and analytical procedures

Approximately 1,400 cubic meters of ambient air per day are drawn through an 8-inch diameter microsorban filter for the land stations. For the ocean stations, about 2,200 cubic meters of air

per day are filtered by an 8- by 10-inch microsorban filter. Each filter is changed on the 1st, 8th, 15th, and 22nd of the month or more frequently if the filter becomes clogged with debris suspended in the air. Under normal conditions, the filters from each station are compressed into a monthly composite and the gamma spectrum of the composite is obtained by an 8- by 4-inch NaI (TI) crystal, approximately 2 weeks after the last collection in the month.

The integrated response between 100 keV and 3.0 MeV is corrected by the average detection efficiency (35 percent) of the gamma photons present in fallout and the total gamma radioactivity is reported in units of photons/min/1,000 m³. Average monthly gamma concentrations are calculated by weighting the concentrations in each sampling interval by the relative period of time in the interval. After the gamma measurements have been completed, monthly composites from each site are submitted to contractor laboratories for radiochemical analyses. Since the last major nuclear weapon test series occurred at the end of 1962, only the longer lived artificially produced radionuclides were present in the filters analyzed prior to May 1966. Consequently, emphasis was given to the determination of manganese-54, iron-55, strontium-90, cadmium-109, cesium-137, cerium-144, plutonium-238, and plutonium-239. Strontium-90, zirconium-95, and cerium-141 were analyzed in samples collected after the foreign nuclear test of May 1966.

The longer lived fission products and plutonium-239 concentrations should describe the general distribution in surface air of all previous nuclear

¹ Summarized from "Fallout Program Quarterly Summary Report," HASL-184, 227, available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.



Figure 1. 80th Meridian Network sampling stations

Table 1. Manganese-54 concentrations in surface air, January-December 1966^a

Site	Concentration (dpm/1,000 standard m ³ at midmonth)						
	Latitude	Longitude	Elevation (meters)	January	February	March	April
Greenland: Thule	76°36'	08°35'	259	NA	221.34	259.95	215.01
Ocean station: Bravo	56°30'	51°00'	0	NA	80.20	128.02	215.02
Charlie	52°45'	35°30'	0		80.29	128.05	128.05
Ontario: Moosonee	51°16'	80°30'	10	87.28	105.98	139.96	88.99
Wash: Seattle	47°36'	122°20'	3				
Ocean station: Delta	44°00'	41°00'	0	NA	97.87	151.90	125.05
N.J.: Westwood	41°00'	74°01'	38	NA	NA	NA	147.50
N.Y.: New York City	40°48'	73°58'	38	82.52	83.10	173.61	135.25
Va: Sterling	38°58'	77°25'	76	72.94	88.94	140.41	84.24
Ocean station: Echo	35°00'	48°00'	0	NA	212.11	182.02	143.05
Fla: Miami	25°49'	80°17'	4	122.30	137.21	237.65	250.81
Bahamas: Bimini	25°46'	79°22'	3				
Hawaii: Mauna Loa	19°28'	155°36'	3,401	170.29	146.25	307.51	189.44
P.R.: San Juan	18°26'	66°00'	20	48.59	119.45	203.42	97.38
Panama: Balboa	8°58'	79°24'	23	49.36	88.99	127.03	68.75
Ecuador: Guayaquil	2°10'	79°52'	7	^b 17.94	^b 22.18	^b 35.41	^b 15.26
Peru: Lima	12°01'	77°08'	13	47.38	69.55	44.11	^b 12.92
Bolivia: Chacaltaya	16°21'	08°07'	5,220	^b 27.05	NA	^b 49.15	^b 45.32
Chile: Antofagasta	23°37'	70°16'	31	46.54	48.69	^b 31.42	^b 35.82
Portillo	32°50'	70°08'	2,850				
Santiago	33°27'	70°42'	520	57.91	64.35	38.96	NA
Puerto Montt	41°27'	72°57'	7	31.16	41.18	33.37	45.05
Punta Arenas	53°08'	70°53'	35	27.74	^b 15.44	^b 33.41	^b 20.90
Pedro Aquire Cerda	62°56'	60°26'	16				

^a No analyses were reported for May through December 1966.

^b Counting error is 20-100 percent.

NA, no analysis.

Table 2. Iron-55 concentrations in surface air, January-December 1966

Site	Concentration (dpm/1,000 standard m ³ at midmonth)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland: Thule	NA	189.81	290.40	147.99	129.47	106.27	89.24	76.53	14.45	NA	28.45	47.92
Ocean station: Bravo	NA	61.40	130.96	82.32	87.72	62.57	124.04	40.29	14.80	13.77	28.26	18.27
Charlie	NA	99.59	169.98	177.09	67.87	70.33	47.65	58.49	16.37	9.80	19.61	19.64
Ontario: Moosonee	76.54	94.98	176.86	105.05	109.95	126.75	152.49	63.38	33.59	26.33	25.70	34.52
Wash: Seattle	NA	104.88	220.44	100.92	149.04	81.86	81.48	45.60	25.55	23.72	32.65	^a 10.31
Ocean station: Delta	75.50	93.89	166.40	133.74	138.89	94.26	72.82	97.40	31.16	^a 18.52	NA	^a 27.78
N.J.: Westwood	73.35	77.53	136.13	147.50	162.94	203.09	159.13	60.45	39.32	NA	25.88	NA
N.Y.: New York City	99.58	86.62	208.75	139.51	290.70	276.16	253.48	87.97	34.80	24.54	63.57	82.78
Va: Sterling	83.22	106.39	228.70	115.53	198.81	243.38	217.91	117.20	^a 20.63	54.68	^a 15.04	^a 46.91
Ocean station: Echo	NA	161.97	254.13	163.00	199.01	67.81	NA	51.95	^(b)	18.88	27.22	22.51
Fla: Miami	146.91	125.58	312.94	264.32	130.12	95.95	75.49	^a 1.39	^a 5.55	26.46	^a 34.49	79.17
Bahamas: Bimini	NA	NA	NA	NA	NA	NA	46.72	92.25	^a 40.55	130.95	129.71	^a 70.15
Hawaii: Mauna Loa	191.07	229.95	295.90	244.10	210.00	198.26	157.19	59.23	^a 10.51	^a 17.61	^a 41.32	54.50
P.R.: San Juan	56.78	134.04	270.94	115.74	108.63	101.54	96.01	^b 68.36	^a 14.93	^a 7.69	^a 19.14	41.26
Panama: Balboa	55.75	78.84	141.47	84.64	35.14	91.71	22.91	^a 6.01	NA	NA	NA	^(b)
Ecuador: Guayaquil	^a 12.71	23.82	^a 16.03	^a 31.75	NA	^a 15.27	^a 26.04	40.96	NA	NA	NA	^a 25.92
Peru: Lima	55.11	53.91	61.15	^a 33.85	31.71	29.92	60.10	^a 54.66	^a 27.91	172.25	^a 28.57	130.10
Bolivia: Chacaltaya	29.45	25.21	31.27	^a 22.84	23.77	52.12	61.90	168.80	157.93	55.37	141.74	96.84
Chile: Antofagasta	55.97	48.60	38.65	44.23	27.32	^a 23.46	54.97	NA	^a 8.70	45.94	108.79	^(b)
Portillo	NA	NA	NA	NA	144.33	40.94	312.00	214.66	NA	NA	NA	590.91
Santiago	77.97	138.49	124.85	^a 98.07	NA	^a 18.80	^a 61.85	^a 35.28	NA	^a 39.14	^(b)	^a 76.47
Puerto Montt	39.77	48.34	50.12	^a 42.59	16.95	10.84	20.22	37.62	^a 6.26	14.25	NA	^a 70.83
Punta Arenas	NA	49.86	45.73	^a 23.51	^a 7.83	11.29	15.83	19.33	NA	NA	NA	^a 31.38

Errors are less than 20 percent except:

^a Counting error is 20-100 percent.

^b Counting error is greater than 100 percent.

NA, no analysis.

weapon debris which was transferred from the lower stratosphere to the troposphere during the collection period of this report. Other tracer radionuclides can be associated with debris from a single detonation or a series of detonations. Manganese-54 and iron-55 were produced in large

quantities in the 1961 and 1962 test series. Cadmium-109 was generated by the United States high altitude test over Johnston Island on July 9, 1962. While plutonium-238 is present in low concentrations in nuclear weapons debris, about 17,000 curies of plutonium-238 were disseminated at high alti-

Table 3. Strontium-90 concentrations in surface air, January-December 1966^a

Site	Concentration (dpm/1,000 standard m ³ at midmonth)							
	May	June	July	August	September	October	November	December
Greenland: Thule.....	^b 85.15	NA	7.24	4.49	8.65	^b 4.15	107.61	34.47
Ocean station: Bravo.....	2.16	4.84	^b 2.20	9.20	NA	NA	14.30	10.40
Charlie.....	NA	NA	9.90	6.27	^b 1.44	^b 8.1	36.32	12.12
Ontario: Moosonee.....	NA	23.00	NA	5.98	NA	NA	40.44	13.95
Wash: Seattle.....	NA	4.69	9.08	14.55	^b 11.41	NA	28.35	5.28
Ocean station: Delta.....	NA	14.20	20.60	6.45	NA	(c)	36.11	13.42
N.Y.: New York City.....	26.71	44.04	28.43	9.91	5.72	4.81	70.22	56.48
Va: Sterling.....	20.86	60.52	51.00	7.40	^b 5.82	NA	68.56	^b 10.77
Ocean station: Echo.....	^b .66	15.94	NA	5.89	NA	(c)	30.89	NA
Fla: Miami.....	101.61	95.19	^b 26.06	10.90	^b 1.63	11.17	100.76	NA
Bahamas: Bimini.....	NA	NA	6.28	15.00	^b 16.67	NA	161.34	23.91
Hawaii: Mauna Loa.....	108.03	332.40	40.07	6.53	^b 4.12	NA	^b 14.10	NA
P.R.: San Juan.....	40.05	70.44	30.32	NA	NA	(c)	21.72	NA
Panama: Balboa.....	18.51	9.15	8.14	4.27	3.54	5.43	14.57	^b 7.11
Ecuador: Guayaquil.....	NA	2.06	209.90	5.20	10.81	133.25	107.67	85.29
Peru: Lima.....	^b .56	5.35	481.84	40.69	^b 23.28	976.06	301.16	100.35
Bolivia: Chacaltaya.....	NA	34.07	1,674.60	74.44	1,103.45	1,329.11	609.57	168.42
Chile: Antofagasta.....	NA	NA	242.83	NA	254.67	763.34	149.70	73.00
Portillo.....	7.76	NA	680.00	128.27	NA	NA	NA	421.21
Puerto Montt.....	NA	NA	225.54	40.18	73.37	186.16	148.64	78.99
Punta Arenas.....	.70	NA	1.85	20.06	4.68	17.89	60.75	26.10
			.99	4.01	4.36	12.53	16.49	6.76

^a No analyses were reported for January through April 1966.
 Errors are less than 20 percent except:
^b Counting error is 20-100 percent.
^c Counting error is greater than 100 percent.
 NA, no analysis.

Table 4. Strontium-90 concentrations in surface air, January-December 1966

Site	Concentration (dpm/1,000 standard m ³ at midmonth)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland: Thule.....	NA	23.03	23.89	NA	13.19	12.80	7.12	5.74	4.92	4.54	2.54	5.11
Ocean station: Bravo.....	NA	8.90	12.60	20.91	5.99	7.05	3.79	4.08	^a 1.95	.91	1.38	1.69
Charlie.....	NA	5.20	13.70	15.31	8.42	5.45	3.30	4.33	2.17	1.62	2.39	1.48
Ontario: Moosonee.....	^a 8.88	11.08	11.46	11.90	15.93	13.55	13.66	5.53	3.79	2.48	3.48	2.17
Wash: Seattle.....	7.40	8.86	12.89	14.00	9.85	9.21	5.59	^a 5.06	3.29	2.14	2.96	2.18
Ocean station: Delta.....	NA	9.18	16.39	13.50	14.79	11.49	7.15	3.20	4.16	2.23	2.70	1.63
N.J.: Westwood.....	11.22	12.32	20.53	17.57	22.98	31.74	19.64	8.87	5.49	NA	3.74	NA
N.Y.: New York City.....	9.46	7.85	17.99	17.13	24.86	23.77	18.46	8.95	6.00	4.27	4.56	4.23
Va: Sterling.....	9.19	10.32	15.87	12.28	25.54	24.69	16.64	8.26	4.97	4.12	3.94	3.97
Ocean station: Echo.....	NA	17.01	17.60	19.51	22.22	5.30	NA	5.04	4.33	2.03	2.40	1.71
Fla: Miami.....	12.35	11.68	19.93	29.46	(d)	11.47	5.61	.99	1.73	2.86	6.77	4.82
Bahamas: Bimini.....	NA	NA	NA	NA	NA	NA	14.53	8.64	3.55	6.81	3.53	4.95
Hawaii: Mauna Loa.....	16.23	16.88	33.17	28.17	28.32	19.83	13.73	5.19	3.90	2.21	3.95	7.25
P.R.: San Juan.....	5.63	12.98	15.81	12.00	11.22	13.47	5.75	5.39	2.70	1.14	2.87	2.92
Panama: Balboa.....	5.93	9.33	10.87	8.46	2.89	.67	.99	1.06	^a .22	^a .18	1.66	1.64
Ecuador: Guayaquil.....	1.88	2.19	1.22	1.16	1.07	1.54	2.33	3.27	1.61	2.06	5.38	3.18
Peru: Lima.....	7.71	7.07	4.69	3.64	2.51	2.42	6.44	4.58	6.53	11.10	10.68	6.53
Bolivia: Chacaltaya.....	3.31	1.96	3.11	2.31	2.86	5.42	13.10	5.08	^a 25.41	9.37	13.48	7.61
Chile: Antofagasta.....	6.70	5.52	3.29	2.96	2.57	2.41	5.36	3.96	4.93	11.23	4.67	3.39
Portillo.....	NA	NA	NA	NA	7.51	4.64	^a 130.29	24.35	NA	NA	NA	40.91
Santiago.....	8.31	10.00	5.21	^a 4.41	3.06	2.40	6.00	4.85	3.40	4.65	7.16	5.13
Puerto Montt.....	4.47	5.09	3.04	2.75	1.64	^a 1.46	1.35	3.06	1.64	1.85	1.29	1.60
Punta Arenas.....	2.00	2.48	2.89	1.72	1.19	1.19	1.42	1.84	1.24	.67	.90	1.11

Errors are less than 20 percent except:
^a Counting error is 20-100 percent.
^b Counting error is greater than 100 percent.
 NA, no analysis.

tude in the stratosphere on April 21, 1964 during the reentry burnup of a SNAP-9A power source.

During 1966, Food, Chemical, and Research Laboratories, Incorporated (FCRL) of Seattle, Wash., performed the analyses of most of the samples in this program. Isotopes, Incorporated

of Westwood, N. J., analyzed most of the samples collected at Westwood, N.J., and a few samples from Chacaltaya, Bolivia, Antofagasta and Santiago, Chile. Previous reports containing data on the HASL Surface Air Sampling Program are given in references 1-7.

Table 5. Zirconium-95 concentrations in surface air, January-December 1966^a

Site	Concentration (dpm/1,000 standard m ³ at midmonth)							
	May	June	July	August	September	October	November	December
Greenland: Thule	4.71	34.10	9.36	2.98	2.25	1.39	30.14	12.35
Ocean station: Bravo	2.65	7.20	13.50	86.31	2.72	3.75	12.29	11.36
Charlie	5.34	6.60	10.80	4.08	2.46	1.07	23.66	4.83
Ontario: Moosonee	8.80	25.50	12.98	2.26	2.15	2.91	33.15	8.90
Wash: Seattle	52.78	16.26	11.58	4.18	2.06	1.46	17.19	2.51
Ocean station: Delta	8.04	26.78	34.97	1.79	2.73	6.07	36.89	4.07
N.Y.: New York City	44.08	53.37	33.92	5.01	2.99	6.11	113.14	15.77
Va: Sterling	29.83	78.44	251.24	6.27	3.32	1.36	45.48	12.24
Ocean station: Echo	37.98	30.78	NA	3.29	1.70	1.24	24.96	(c)
Fla: Miami	59.06	120.25	16.10	23.91	6.92	6.33	190.82	10.39
Bahamas: Bimini	NA	NA	107.81	12.29	3.94	9.48	185.30	11.35
Hawaii: Mauna Loa	81.07	411.15	50.34	5.47	4.26	17.61	29.76	27.81
P.R.: San Juan	89.45	132.39	57.21	6.91	2.68	9.93	18.00	12.56
Panama: Balboa	15.43	15.41	9.82	5.00	2.40	11.11	13.23	7.21
Ecuador: Guayaquil	NA	10.51	38.04	4.97	26.29	15.18	234.01	129.13
Peru: Lima	5.51	5.91	702.18	141.18	87.53	1,114.83	700.68	330.10
Bolivia: Chacaltaya	3.32	47.03	408.73	556.39	1,255.17	2,502.11	1,504.35	408.42
Chile: Antofagasta	1.24	NA	543.05	95.97	7.73	18.28	287.88	127.22
Portillo	42.47	26.59	1,451.43	361.20	NA	NA	NA	974.24
Santiago	NA	NA	403.08	154.29	13.90	2.43	345.14	180.07
Puerto Montt	NA	NA	41.10	51.82	11.74	42.98	156.39	55.81
Punta Arenas	NA	NA	5.92	10.52	7.74	22.34	30.62	28.46

^a No analyses were reported for January through April 1966.

Errors are less than 20 percent except:

^b Counting error is 20-100 percent.

^c Counting error is greater than 100 percent.

NA, no analysis.

Table 6. Cadmium-109 concentrations in surface air, January-December 1966

Site	Concentration (dpm/1,000 standard m ³ at midmonth)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland: Thule	NA	NA	71.66	72.39	70.53	NA	NA	NA	21.55	NA	NA	(b)
Ocean station: Bravo	NA	NA	50.92	27.09	15.83	40.23	NA	NA	26.96	20.60	(b)	54.71
Charlie	NA	1,301.17	21.05	61.05	12.29	37.99	NA	26.75	52.01	NA	NA	NA
Ontario: Moosonee	16.54	NA	63.10	54.59	35.88	NA	49.17	NA	NA	NA	NA	NA
Wash: Seattle	37.25	NA	56.96	NA	40.91	98.09	NA	106.75	NA	70.37	NA	52.47
Ocean station: Delta	NA	NA	56.91	NA	58.15	NA	11.61	NA	20.98	37.50	NA	37.80
N.J.: Westwood	(b)	(b)	(b)	73.46	57.58	99.23	58.19	23.85	NA	35.71	NA	NA
N.Y.: New York City	45.15	NA	93.63	42.20	106.85	108.48	63.50	73.46	41.51	762.20	175.77	9.24
Va: Sterling	NA	130.47	96.86	74.59	51.07	NA	179.85	28.75	NA	NA	NA	70.56
Ocean station: Echo	NA	NA	90.01	2.69	43.95	9.92	NA	NA	125.96	NA	NA	49.19
Fla: Miami	57.04	NA	56.94	99.46	50.12	77.22	NA	NA	NA	73.30	69.62	73.51
Bahamas: Bimini	NA	NA	NA	NA	NA	NA	271.87	294.57	40.94	NA	NA	62.77
Hawaii: Mauna Loa	46.74	45.06	139.25	244.10	152.14	27.60	NA	98.26	NA	NA	NA	(b)
P.R.: San Juan	22.38	NA	329.06	NA	53.48	20.93	NA	46.38	NA	NA	(b)	75.36
Panama: Balboa	16.42	73.04	53.81	NA	25.54	NA	518.04	NA	NA	68.18	NA	97.28
Ecuador: Guayaquil	NA	NA	140.67	NA	NA	NA	59.64	33.41	NA	NA	(b)	NA
Peru: Lima	88.28	NA	200.50	NA	40.49	NA	NA	NA	44.17	NA	NA	74.74
Bolivia: Chacaltaya	42.15	NA	68.64	234.86	NA	NA	76.98	59.02	102.41	345.00	(b)	233.68
Chile: Antofagasta	74.84	34.55	124.44	112.26	NA	NA	44.37	NA	43.69	(b)	NA	(b)
Portillo	NA	NA	NA	NA	148.45	NA	143.43	246.66	NA	NA	NA	322.73
Santiago	NA	NA	247.55	NA	19.07	146.45	36.92	35.89	38.81	NA	NA	78.57
Puerto Montt	57.44	36.87	33.64	34.12	19.30	NA	NA	42.90	NA	230.26	NA	NA
Punta Arenas	NA	NA	73.93	28.32	39.91	NA	148.95	NA	48.95	NA	NA	158.24

Errors are less than 20 percent except:

^b Counting error is 20-100 percent.

^c Counting error is greater than 100 percent.

NA, no analysis.

Results

The updated radioactivity concentrations in surface air during 1966 are presented in tables 1 through 11. The sites are listed according to latitude beginning with the most northern site

at Thule, Greenland. The results of the blank and standard analyses are reported in tables 12 and 13.

The concentrations are reported at the midpoint of the collection month for the plutonium isotopes and the fission products and on the following dates for the induced nuclides:

Table 7. Cesium-137 concentrations in surface air, January-December 1966^a

Site	Concentration (dpm/1,000 standard m ³ at midmonth)			
	January	February	March	April
Greenland: Thule	NA	24.06	38.41	34.32
Ocean station: Bravo	NA	11.30	16.50	25.37
Charlie	NA	7.13	18.42	17.00
Ontario: Moosonee	13.90	15.45	22.27	16.06
Ocean station: Delta	NA	15.91	21.64	15.51
N.J.: Westwood	NA	NA	NA	24.90
N.Y.: New York City	18.27	13.98	26.30	24.18
Va: Sterling	14.12	14.80	27.35	15.32
Ocean station: Echo	NA	24.31	29.75	22.65
Fla: Miami	22.09	20.05	40.47	40.00
Hawaii: Mauna Loa	35.04	22.25	52.22	37.58
P.R.: San Juan	9.82	20.52	26.32	16.36
Panama: Balboa	9.10	13.30	16.75	12.84
Ecuador: Guayaquil	3.46	3.41	2.50	1.97
Peru: Lima	12.54	11.26	6.82	4.90
Bolivia: Chacaltaya	8.31	3.21	4.58	4.17
Chile: Antofagasta	7.99	8.74	17.96	5.14
Santiago	18.25	16.91	9.02	5.88
Puerto Montt	8.98	7.34	4.87	4.02
Punta Arenas	5.29	3.74	4.76	2.91

^a No analyses were reported for May through December.
NA, no analysis.

Manganese-54 and iron-55 : October 15, 1961
Cadmium-109 : July 9, 1962

One standard deviation of the counting error for these data is always less than ± 20 percent and usually less than ± 10 percent unless otherwise indicated.

Data reliability

The quality of the radiochemical analysis is monitored through the use of various "knowns"

submitted to the contractor each month along with regular samples. Basically, there are three kinds of quality control samples: blanks, standards, and duplicates.

A blank is prepared by sprinkling a small amount of pre-1945 soil (10 mg) onto an unexposed microsorban filter. Then, carbon soot from burning naphthalene is filtered onto the microsorban paper for a few moments under laboratory conditions. This procedure produces blanks which are very similar in appearance, and in some re-

Table 8. Cerium-141 concentrations in surface air, January-December 1966^a

Site	Concentration (dpm/1,000 standard m ³ at midmonth)							
	May	June	July	August	September	October	November	December
Greenland: Thule	^b 555.56	19.19	^b 32.85	NA	147.51	NA	^b 48.73	NA
Ocean station: Bravo	261.76	17.97	32.10	81.88	^b 41.54	NA	80.39	(^c) NA
Charlie	NA	^b 33.62	NA	NA	^b 101.93	NA	^b 94.37	NA
Ontario: Moosonee	NA	58.75	NA	NA	^b 94.40	^b 19.70	^b 46.01	(^c) NA
Wash: Seattle	^b 19.90	25.41	^b 26.25	NA	^b 99.25	^b 36.79	NA	NA
Ocean station: Delta	NA	39.05	^b 28.24	^b 27.52	^b 69.72	NA	^b 88.23	^b 221.65
N.Y.: New York City	242.58	68.94	47.31	49.78	^b 77.81	22.77	NA	^b 180.00
Va: Sterling	^b 32.70	^b 97.40	100.50	^b 30.71	NA	^a 24.70	^b 120.15	NA
Ocean station: Echo	^b 26.53	^b 37.97	NA	72.37	^b 44.69	NA	NA	^b 94.90
Fla: Miami	240.00	152.41	58.33	^b 50.95	^b 87.15	^b 12.26	NA	NA
Bahamas: Himni	NA	NA	92.19	^b 60.38	361.02	NA	^b 155.59	NA
Hawaii: Mauna Loa	263.93	585.37	127.74	47.39	NA	NA	NA	NA
P.R.: San Juan	115.59	135.73	77.75	NA	NA	NA	NA	NA
Panama: Balboa	^b 30.81	15.08	^b 16.86	3.93	^b 47.51	NA	NA	^b 391.16
Ecuador: Guayaquil	NA	^b 14.91	539.06	^b 16.57	^b 71.01	^b 304.53	NA	^b 972.97
Peru: Lima	^b 2.98	15.40	113.56	141.18	NA	^b 1,830.14	NA	^b 1,363.32
Bolivia: Chacaltaya	12.43	79.24	650.79	^b 620.30	^b 1,120.60	^b 2,050.63	NA	NA
Chile: Antofagasta	NA	NA	792.49	185.46	NA	2,187.94	NA	NA
Portillo	^b 27.63	16.78	1,571.43	^b 108.90	NA	NA	NA	NA
Santiago	NA	^b 3.64	584.62	199.39	^b 199.22	NA	NA	(^c) NA
Puerto Montt	NA	NA	10.88	139.00	^b 191.55	NA	^b 977.41	NA
Punta Arenas	NA	^b 3.44	9.70	28.51	^b 78.32	NA	^b 217.08	NA

^a No analyses were reported for January through April 1966.
Errors are less than 20 percent except:
^b Counting error is 20-100 percent.
^c Counting error is greater than 100 percent.
NA, no analysis.

Table 9. Cerium-144 concentrations in surface air, January-December 1966

Site	Concentration (dpm/1,000 standard m ³ at midmonth)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland: Thule	NA	50.00	42.30	42.36	28.99	18.97	9.85	8.32	6.30	6.29	1.61	10.30
Ocean station: Bravo	NA	17.41	21.61	25.12	8.07	10.90	5.02	6.70	2.85	.91	4.56	3.77
Ontario: Charlie	NA	9.53	33.37	27.37	13.77	8.29	5.35	6.15	2.77	2.12	8.59	3.78
Washington: Moosonee	17.11	21.10	14.02	17.37	22.30	20.42	23.14	8.56	5.39	3.82	11.46	5.10
Seattle: Seattle	13.67	16.61	23.52	23.59	24.65	14.40	11.60	7.45	4.47	3.31	1.25	3.98
Ocean station: Delta	NA	21.10	27.45	20.63	23.48	18.79	13.90	4.62	5.02	2.44	11.26	3.73
N.J.: Westwood	22.13	22.41	31.30	25.75	48.72	52.25	28.79	10.71	5.96	NA	4.20	NA
N.Y.: New York City	19.80	15.67	31.96	25.96	45.52	46.21	38.06	14.44	6.29	6.44	46.58	11.25
Va.: Sterling	18.26	20.76	28.25	17.41	36.04	45.45	26.36	11.82	6.10	5.37	14.72	7.68
Ocean station: Echo	NA	34.08	34.50	30.27	35.66	12.89	NA	7.16	5.12	2.75	8.43	2.69
Fla.: Miami	30.99	29.20	47.29	45.95	40.41	38.48	12.65	7.25	2.38	5.05	38.61	11.61
Bahamas: Bimini	NA	NA	NA	NA	NA	NA	24.06	13.10	5.39	11.29	60.06	16.55
Hawaii: Mauna Loa	40.94	25.10	56.66	39.75	114.04	113.59	85.99	7.46	5.06	3.47	13.83	16.25
P.R.: San Juan	11.64	26.50	24.79	18.72	24.22	35.73	15.94	8.91	3.70	5.13	7.66	6.10
Panama: Balboa	11.18	20.64	17.64	15.86	6.68	2.26	3.32	2.43	.80	2.51	5.57	3.91
Ecuador: Guayaquil	3.44	4.03	2.04	1.85	1.55	3.99	30.84	6.18	5.31	51.80	36.05	49.25
Peru: Lima	12.99	12.60	7.09	5.00	3.39	5.73	101.21	21.67	22.17	255.02	200.86	115.22
Bolivia: Chacaltaya	5.74	4.94	4.49	4.27	3.92	16.69	583.33	104.14	1,437.93	414.35	361.74	142.11
Chile: Antofagasta	11.76	9.45	4.99	4.45	3.57	5.51	88.74	14.94	17.48	230.86	106.67	53.52
Portillo	NA	NA	NA	NA	15.46	11.16	210.86	95.81	NA	NA	NA	510.61
Santiago	12.71	14.07	8.25	5.53	4.16	3.64	670.77	29.57	15.44	72.79	107.78	88.66
Puerto Montt	8.00	8.62	5.20	7.30	2.46	3.26	2.75	11.06	7.42	8.90	46.02	18.72
Punta Arenas	4.66	4.14	4.17	2.60	1.09	1.44	2.14	3.34	2.78	4.83	10.11	7.55

Errors are less than 20 percent except:
 * Counting error is 20-100 percent.
 NA, no analysis.

Table 10. Plutonium-238 concentrations in surface air, January-December 1966

Site	Concentration (dpm/1,000 standard m ³ at midmonth)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland: Thule	NA	* 0.79	0.80	* 1.92	* 0.96	1.30	* 0.44	* 0.26	2.79	* 2.22	(b)	* 0.30
Ocean station: Bravo	NA	NA	NA	2.61	.80	* .70	1.50	NA	1.10	* 2.52	* 2.27	NA
Ontario: Charlie	NA	NA	.80	4.29	.90	* 1.00	* .40	* 1.30	* .70	* 1.22	(b)	NA
Washington: Moosonee	NA	* 1.72	* .48	NA	* .82	* .64	* 1.49	* 2.80	2.45	* 1.44	* .93	* .81
Seattle: Seattle	* 1.16	NA	* .54	* 2.96	* 1.18	NA	5.07	* .77	3.04	* 1.85	(b)	1.54
Ocean station: Delta	NA	* 1.10	* .80	* 1.30	* 1.00	3.51	* .51	* .70	* .50	* 1.83	* 1.87	NA
N.J.: Westwood	* .74	* .42	.75	7.55	1.73	2.05	22.51	5.47	3.56	2.96	* 1.15	NA
N.Y.: New York City	1.36	1.79	.57	5.07	3.71	8.86	2.97	2.33	2.30	2.90	4.95	3.72
Va.: Sterling	NA	* .41	* .52	NA	91.17	1.87	2.69	* 4.08	5.07	* 1.73	NA	* 1.62
Ocean station: Echo	NA	NA	* .80	* 3.21	2.21	.70	NA	* 4.81	3.39	* 2.81	* 1.95	NA
Fla.: Miami	* 1.18	NA	1.40	* 1.89	* 2.28	* 1.54	* 1.33	NA	1.78	* 1.17	* 1.80	* .83
Bahamas: Bimini	NA	NA	NA	NA	NA	NA	* 1.86	* 5.12	NA	* 4.24	(b)	NA
Hawaii: Mauna Loa	* .66	* 1.95	1.62	5.00	* 2.44	* 1.94	* 1.79	* 5.57	NA	* 1.69	NA	14.62
P.R.: San Juan	* 2.44	* .79	* .38	NA	* 1.98	* .78	* .67	* 3.00	* 4.20	* 3.65	NA	* 1.46
Panama: Balboa	* .78	NA	* .34	NA	NA	NA	NA	NA	1.23	* 2.37	* 3.16	* 5.14
Ecuador: Guayaquil	NA	NA	* .22	NA	* .22	* 1.68	NA	* 1.94	4.45	* 6.24	(b)	7.24
Peru: Lima	NA	NA	9.42	* .44	* 1.32	* 1.31	* 4.94	* 5.17	13.58	24.40	(b)	16.33
Bolivia: Chacaltaya	* .40	NA	* .40	* 6.10	* 2.62	9.03	13.65	* 9.81	91.03	23.21	(b)	* 16.84
Chile: Antofagasta	* .32	* .87	* .33	* 1.51	* 1.37	* 2.03	19.25	* 5.30	* 13.53	24.83	(b)	8.17
Portillo	NA	NA	NA	NA	* 9.55	* 7.39	65.14	* 37.07	NA	NA	NA	95.91
Santiago	* 1.41	* .47	* 1.07	* .95	NA	4.30	2.43	1.51	15.21	* 4.42	* 3.50	11.22
Puerto Montt	* .42	* .94	NA	* 2.28	* .62	2.46	* 1.54	* 11.25	34.93	5.40	* 5.49	* 2.38
Punta Arenas	NA	NA	NA	* 1.57	* .41	* 1.63	NA	* 3.26	4.59	3.66	(b)	(b)

Errors are less than 20 percent except:
 * Counting error is 20-100 percent.
 * Counting error is greater than 100 percent.
 NA, no analysis.

Table 11. Plutonium-239 concentrations in surface air, January-December 1966

Site	Concentration (dpm/1,000 standard m ³ at midmonth)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland: Thule	NA	83.44	37.47	47.18	35.99	19.97	8.06	* 5.48	29.85	3.69	* 3.82	4.40
Ocean station: Bravo	NA	9.20	19.41	45.32	15.09	10.80	3.99	* 3.20	9.30	2.43	* 6.47	2.81
Ocean station: Charlie	NA	7.81	NA	30.74	16.87	8.79	3.89	* 6.80	2.50	3.88	* 6.83	2.04
Ontario: Moosonee	* 7.85	13.37	26.64	30.05	23.38	20.00	16.20	* 5.18	18.50	26.79	* 3.86	3.95
Wash.: Seattle	7.90	11.86	24.36	36.65	25.16	12.87	12.59	1.76	20.06	5.86	11.83	3.95
Ocean station: Delta	NA	* 12.20	33.27	25.05	23.88	* 14.10	6.70	2.70	10.80	27.96	* 2.75	* 1.72
N.J.: Westwood	29.19	17.15	31.04	* 48.50	48.02	71.35	78.64	12.45	9.51	5.87	5.96	NA
N.Y.: New York City	16.48	5.95	34.13	46.64	87.15	33.21	27.45	18.32	12.20	17.42	12.27	15.72
Va.: Sterling	13.62	10.12	30.04	27.76	41.53	37.68	24.23	11.15	46.75	8.49	8.19	5.80
Ocean station: Echo	NA	13.86	32.62	41.26	39.80	5.20	NA	15.10	7.60	6.02	* 7.19	* 4.85
Fla.: Miami	27.70	NA	50.12	61.08	16.82	17.44	8.11	* 1.77	11.54	* 5.75	5.85	6.90
Bahamas: Bimini	NA	NA	NA	NA	NA	NA	13.44	12.36	188.38	13.38	46.33	8.18
Hawaii: Mauna Loa	28.45	24.19	58.36	50.93	44.29	38.33	16.92	* 11.15	NA	4.47	6.65	14.81
P.R.: San Juan	9.74	24.80	29.74	24.49	25.42	14.37	7.75	7.97	84.47	7.58	2.71	6.79
Panama: Balboa	9.16	9.30	17.87	* 1.12	7.00	* .78	* 2.58	* 3.69	14.46	3.79	5.84	7.14
Ecuador: Guayaquil	* 2.34	4.79	2.97	3.02	1.65	* 1.80	30.21	4.62	6.83	* 11.06	* 4.13	8.41
Peru: Lima	6.98	15.84	* 1.22	19.33	5.32	3.17	43.34	5.61	16.78	NA	* 3.10	19.55
Bolivia: Chacaltaya	5.86	* 7.92	6.06	12.06	3.22	8.43	61.90	* 26.28	157.93	43.88	* 12.35	32.21
Chile: Antofagasta	10.97	9.27	5.19	7.45	3.13	4.83	44.37	9.44	60.51	29.47	* 17.88	11.28
Fortillo	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Santiago	6.95	9.94	8.10	9.23	NA	5.12	13.88	10.80	13.63	10.74	16.07	17.52
Puerto Montt	6.98	11.74	5.27	6.31	2.66	3.59	* 4.73	9.08	25.34	6.58	13.01	7.62
Punta Arenas	* 4.63	4.36	4.79	4.29	2.03	2.03	2.96	* 8.74	17.55	3.20	* 8.43	* 4.87

Errors are less than 20 percent except:

* Counting error is 20-100 percent.

NA, no analysis.

Table 12. Quality control results on blank samples—1966
(Average values in dpm per sample)

Month (1966)	Manganese-54	Iron-55	Strontium-89	Strontium-90	Zirconium-95	Cadmium-109	Cesium-137	Cerium-141	Cerium-144	Plutonium-238	Plutonium-239
January	288	* 47		b 1.0		b 16	b 1.1		0	b 0.1	b 0.1
February	* 150	* 47		b 1.0		* 20	b 2.0		b 1.3	b .1	b .3
March	475	* 123		b .2		0	44.5		0	0	b .1
April	0	207		b .6		0	b 3.3		b 3	b .1	0
May		0	b .8	0	0	0		0	0	b .3	b .1
June		* 104	0	0	0	0		* 56	b 4	b .1	b 1.0
July		139	0	0	310	0		* 100	b 4	b .1	b 1.0
August		0	0	0	102	b 14		0	3	0	0
September		0	b 2	b .4	0	0		584	0	b .8	* 13.0
October		0	0	0	b 47	b 27		4,000	0	b 1.3	b 3.7
November		0	* 33	0	b 12	* 54		b 0	b 2	b .3	b .2
December		0	0	b .7	b 0	b 0		b 0	b 1	0	b .2

One standard deviation of counting error is ± 20 percent except for:a = ± 20 percent to ± 100 percent.b = greater than ± 100 percent.Table 13. Quality control results on standard samples—1966
(Average values in percent deviation)

Month (1966)	Manganese-54	Iron-55	Strontium-89	Strontium-90	Zirconium-95	Cadmium-109	Cesium-137	Cerium-141	Cerium-144	Plutonium-238	Plutonium-239
January	-2	-17		-2		-28	-1		+15		-8
February	+10	-18		-10		-86	0		+38		-46
March	-50	+13		-6		+4	-34		-14		-10
April	-2	-5		-30		-75	-40		-14		+18
May		-10		-4		-2			-1		+10
June		-58		+12	+19	-17		-1	-10		+10
July		+43	-18	-11	+23	-26		-72	+20		-58
August		+2	-32	+10	+29	-19		+700	-24	-23	+30
September		-36	-40	-9	+25	-40		+250	-9	-36	+870
October		-1	-24	-8	+100	-34		+1,000	-100	-24	+2
November		+28	-15	+2	-8	-14		+10	+16	+200	+62
December		+31	+49	-78	-9	-22		+69	+109	-93	-59

Table 14. Quality control results on duplicate samples—1966
(Values are $\pm$ percent standard deviation)

Month (1966)	Manga- nese-54	Iron- 55	Stron- tium-90	Stron- tium-90	Zirc- onium-95	Cadmium- 109	Cesium- 137	Cerium- 141	Cerium- 144	Pluto- nium-238	Pluto- nium-239
January	9	4		9		176	8		2	70	5
February	10	6		4		—	1		2	45	14
March	5	13		5		64	2		1	42	4
April	3	10		1		—	3		2	—	32
May		11	2	8	24	54		54	3	96	16
June		18	28	2	31	27		17	2	90	38
July		3	36	1	11	5		38	14	33	76
August		170	5	38	27	—		2	6	15	20
September		46	—	10	8	74		—	58	76	23
October		37	16	9	45	—		37	16	58	9
November		11	43	3	61	40		—	76	6	36
December		23	—	32	13	—		21	2	61	74

spects, composition to the routine filters collected by this program. When the blanks are coded, as are all the filters submitted to radiochemistry, they are not readily distinguishable from routine samples. Table 12 lists the results of analyses of blanks in 1966. The table summarizes the average dpm reported from blanks sent out each month. It is evident from a review of these data that the contamination problem has been quite variable, and consequently low level concentrations in the real samples must be considered with care.

A standard is prepared at HASL onto a blank sample. A few drops of wetting agent is applied to the blank prior to the addition of the standard to permit permeation of the solution between the polyethylene fibers of the microsorban filter. Table 13 presents the results of these analyses for each nuclide in 1966. The values are average percent deviations of the reported analyses from the known. Again the results are seen to be extremely variable and generally nonsystematic.

Duplicate collections are made monthly at the New York site. These samples are composited and split before analyses thereby providing a measure of the reproducibility of the radiochemical procedures. The results of these tests are shown as the percent standard deviation from the mean, in table 14.

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- (7) KREY, P. W. Surface Air Sampling Program, HASL-182, AEC Health and Safety Laboratory, 376 Hudson Street, New York, N.Y. 10014 (July 1, 1967).

Data for 1967-1969 available in HASL-227

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January-December 1965	January 1967

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included

here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Radionuclides in Alaskan Caribou and Reindeer, May-December 1969

*Bureau of Radiological Health
U.S. Public Health Service*

Under a cooperative agreement between the Alaskan Department of Health and Welfare, the Alaskan Department of Fish and Game, and the U.S. Public Health Service, a program of caribou and reindeer sampling and analysis was undertaken in 1963 to aid in the assessment of radionuclide intake of Alaskan residents. This joint sampling activity was continued based on

results of a limited sampling effort conducted by these groups in 1962.

Through the second quarter of 1964, the sampling was confined to the three principal caribou herds and one privately-owned reindeer herd. This program was expanded in September 1964, when the sampling of additional privately-owned and government-owned reindeer herds was begun

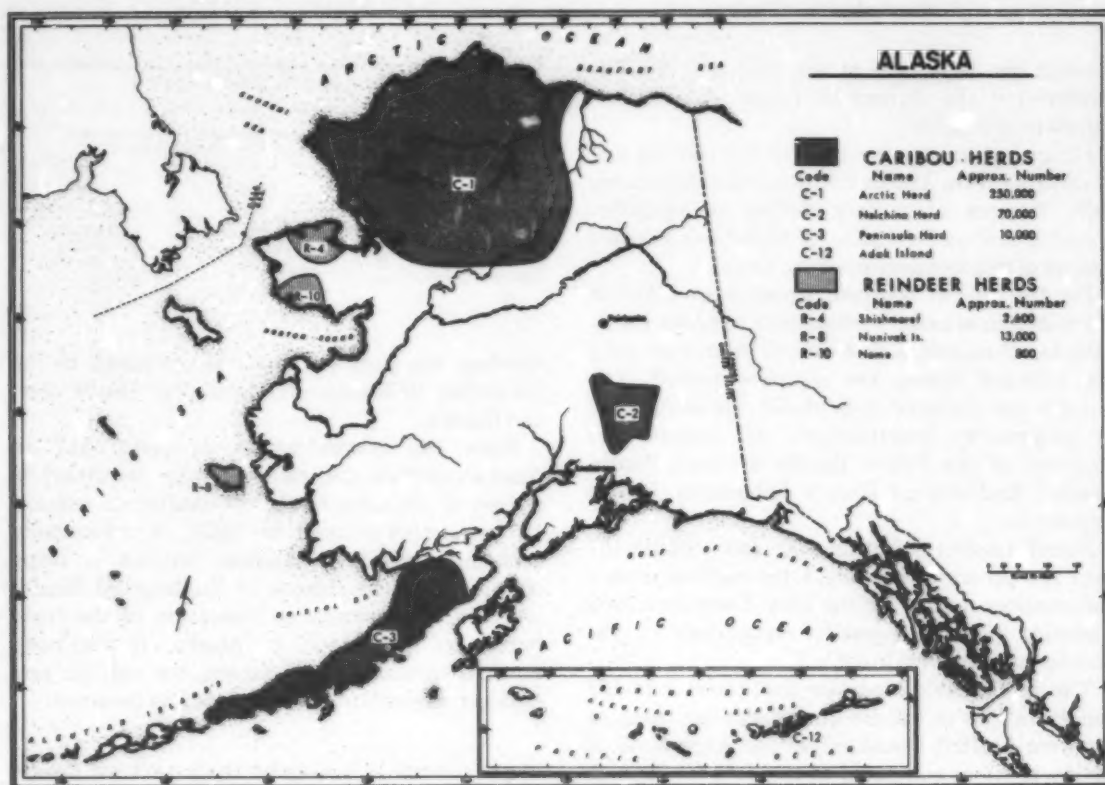


Figure 1. Locations of caribou and reindeer herds sampled in Alaska

Table 1. Radionuclide concentration in muscle of Alaska caribou and reindeer, May-December 1969

Herd and sampling locations ^a	Collection date (1969)	Sex	Age (years)	Concentration (pCi/kg wet weight)		Cesium-137 concentration (nCi/kg wet weight)
				1968	1969	
Arctic caribou herd: Anaktuvuk Pass, C-1	10/10	F				2.1
	10/10	M				4.7
	10/10	M				3.2
	10/11	F				3.4
	10/11	M				4.1
Nelchina caribou herd: Dickey Lake, C-2	10/9	M				2.6
	10/10	M				5.5
	10/10	F				4.0
	10/11	F				4.4
	10/11	F				4.6
Peninsula caribou herd: King Salmon, C-3	9/29	F				2.6
	9/29	M				6.8
	9/30	F				1.5
	9/30	F				2.0
	10/9	F				5.1
Shishmaref reindeer herd: Seward Peninsula, R-4	5/6	F		b.c 0	b.g	11
	5/6	M				15
	5/6	F				14
	5/6	M				15
	5/6	M				12
	12/14	F	2	0	5	12
	12/14	M	2	0	6	12
	12/14	M	2	0	7	11
	12/14	M	2	0	<4	11
	12/14	F	.7	0	6	15
Adak caribou herd: Adak Island:	8/14	M				2.4
	8/14	F				1.6
	8/14	F				2.1
	8/13	F				2.1

^a Sampling locations are shown in figure 1.
^b Composite of individual samples taken within herd.
^c All results ≤ 5 pCi/kg wet weight are reported as 0.

through the assistance of the Fish and Wildlife Service and the Bureau of Indian Affairs, Department of Interior.

Figure 1 shows the locations of the caribou and reindeer herds in Alaska that were sampled during 1969. Because of nuclear testing at Amchitka Island, a caribou herd at Adak Island was sampled instead of reindeer samples from Nome.

For the present program, samples are taken in the fall from selected caribou and reindeer herds. Samples of muscle of five animals from each herd are collected during the sampling period. The samples are analyzed individually for cesium-137 by gamma-ray spectroscopy. All samples are analyzed at the Public Health Service's Southwestern Radiological Health Laboratory in Las Vegas, Nev.

Strontium-89, strontium-90, and cesium-137 data are presented in table 1 for caribou muscle and reindeer muscle for the May-December 1969 collection period. A yearly comparison of the muscle data is shown in table 2.

The data in table 2 indicate that the cesium-137 concentrations in muscle during similar times of the year in 1969 remained at the same level of radioactivity as compared to the data for 1968. A summary of the strontium-90 and cesium-137 concentrations in foodstuffs in Alaska (including

Table 2. Cesium-137 concentrations in caribou and reindeer muscle, 1968 and 1969

Herd	Average cesium-137 concentration (nCi/kg wet weight)	
	1968	1969
Arctic caribou	5 (October)	4 (October)
Nelchina caribou	2 (September)	4 (October)
Peninsula caribou	5 (October)	4 (September)
Shishmaref reindeer	15 (April)	13 (May)
	11 (November)	12 (December)

reindeer and caribou meat) is contained in the December 1966 issue of *Radiological Health Data and Reports*.

Since the concentrations of cesium-137 in Alaskan caribou and reindeer have continued to remain at the same levels, the analysis of cesium-137 was discontinued in 1970. A whole-body counting project of Alaskan natives is being continued by the Bureau of Radiological Health and will still provide an indication of the body burden of the people in Alaska. If the body burdens increase in the future, the caribou and reindeer surveillance program can be resumed.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
March-May 1968	December 1968
September-November 1968	June 1969

Radiological Health Data and Reports

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational

Safety in directives published in the "AEC Manual."¹

Summaries of the environmental radioactivity data follow for the Knolls Atomic Power Laboratory and the Portsmouth Area Gaseous Diffusion Plant.

¹ Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Knolls Atomic Power Laboratory² January-December 1968

*General Electric Company
Schenectady, N. Y.*

The principal function of the Knolls Atomic Power Laboratory (KAPL), operated by the General Electric Company for the Atomic Energy Commission, is to support the Naval Reactors Program of the AEC in the development of atomic power for naval propulsion. This includes design, construction, and prototype operation of nuclear power reactors. The Knolls Atomic Power Laboratory consists of two sites, the Knolls site and the Kesselring site (figure 1).

Knolls site

The Knolls site occupies approximately 170 acres on which are located administrative buildings; chemistry, physics, metallurgical, engineering, and radioactive materials laboratories; critical assembly buildings; machine shops, decontamination facilities; radioactive waste storage and processing facilities; and nuclear fuel storage and assembly buildings.

The Knolls site releases small amounts of radioactive materials both to the atmosphere and to the Mohawk River. Prior to release, exhaust air and liquid waste are treated and carefully monitored. In addition to the inplant control

² Summarized from "Knolls Atomic Power Laboratory, Knolls Site and Kesselring Site: Annual Environmental Monitoring Report, January-December 1968."



Figure 1. Environmental monitoring locations, KAPL.

monitoring, an environmental monitoring program is conducted both on- and offsite at the Knolls site to: (1) audit the operational control of radioactive waste release to the environment, and (2) to ascertain compliance with the radioactivity standards established by the AEC.

Air monitoring

Environmental airborne radioactivity is measured at two locations at the Knolls site and at

one location at the General Electric Company Research and Development Center, approximately 1 mile west of the Knolls site.

The results of the beta-gamma radioactivity analyses of environmental air at the Knolls and offsite sampling locations show average concentrations of 71 fCi/m³ and 95 fCi/m³, respectively. The results were all less than the most restrictive permissible airborne concentrations for beta-emitting radionuclides given in AEC Manual Chapter 0524 (strontium-90, 30 pCi/m³). Most of the environmental air results were less than 50 fCi/m³, the value considered valid at the 90-percent confidence level with an error of 30 percent. The maximum concentration (250 fCi/m³) was detected during the second week of May 1968.

In addition to the environmental airborne radioactivity monitoring, surveys are made routinely of the radiation levels at the perimeter of the Knolls site facilities. The surveys of 1968 showed normal background radiation levels for the geographic location. The results of the surveys extrapolated to an annual exposure, indicate average radiation levels of <0.1 R/a.

Liquid waste monitoring

All sources of liquid radioactive waste at the Knolls site are connected by control drains to collection tanks in the radioactive waste processing building. The release of liquid waste to the Mohawk River is regulated through the control and monitoring of the concentration of radioactive materials in the collection tanks and control of the discharge of the effluent.

A continuous proportional sample of the Knolls site combined sewer effluent is collected at the point of discharge to the Mohawk River. Radiochemical analyses of weekly composite samples show that strontium-90 is the principal component to be considered in control.

A total of 56.7 millicuries of beta and 6.2 millicuries of alpha radioactivity was discharged to the Mohawk River during 1968. The average annual concentration of strontium-90, which comprised 32.5 percent of the total beta radioactivity in the effluent, was 12 pCi/ml or 4 percent of its environmental standard as given in AEC Manual Chapter 0524. The average annual gross alpha concentration was less than 1 percent of the AEC standard for plutonium-239 (5 nCi/liter).

Water monitoring

Mohawk River water is sampled continuously at the General Electric Company powerhouse, 8 miles upstream from the Knolls site; at the Vischer Ferry powerhouse, 1.7 miles downstream; and at the Cohoes, N.Y., pumping station, 13 miles downstream. A continuous sample of Cohoes municipal water, which is derived from river water, is also collected at the Cohoes pumping station. The weekly water samples are composited and analyzed for radioactivity on a monthly basis. Average quarterly beta-gamma concentrations are given in table 1.

Table 1. Radioactivity in Mohawk River water near the Knolls site, 1968

Sampling period (1968)	Beta-gamma radioactivity (pCi/liter)			
	G.E. Powerhouse (upstream)	Vischer Ferry (downstream)	Cohoes raw water (downstream)	Municipal water
January-March.....	9	1	5	2
April-June.....	6	2	3	3
July-September.....	5	6	7	8
October-December.....	6	6	5	3

Sediment monitoring

The Mohawk River monitoring program at the Knolls site consists of a quarterly collection and analysis of Mohawk River sediment. Samples are collected at 15 specific locations and all are analyzed for gamma (cesium-137 equivalent), gross beta (cesium-137 equivalent) and alpha (plutonium-239 equivalent) radioactivity content; in addition, three of the samples are analyzed for strontium-90 content. The Knolls site radioactive liquid waste disposal program did not significantly influence the radioactivity levels of the Mohawk river sediment. In three of the four quarters, the sample location yielding the highest results was location No. 4. This location is directly downstream from the Knolls site sewer outfall to the river. General concentrations rapidly diminished with increased distances from the sewer outfall. The radioactivity concentrations in Mohawk River sediment samples are given in table 2.

Table 2. Radioactivity concentrations in Mohawk River sediment, KAPL, 1968*

1968	Number of samples	Total radioactivity (pCi/g)				Strontium-90 (pCi/g)		Cesium-137 (pCi/g)	
		Alpha		Beta					
		Average	Range	Average	Range	Average	Range	Average	Range
January-March.....	15	0.70	0.2-1.3	14	7.9-42	0.21	0.1-0.4	4.3	0.4- 52.9
April-June.....	15	.96	.3-4.5	12	5.0-21	.90	.6-1.1	2.5	.2- 26.9
July-September.....	15	.66	.3-3.1	18	8.3-87	1.33	.2-3.3	15.5	8-206
October - December.....	13	.81	.4-1.8	16	10 -24	.49	.3- .9	5.8	1.4- 21.2

* Minimum detectable concentration for a 600 g sample at 90-percent confidence level:

Alpha—0.1 pCi/g

Beta—9.0 pCi/g

Strontium-90—1.1 pCi/g

Cesium-137—0.4 pCi/g

Concentrations for 600 g sample detectable at 90-percent confidence level with 30 percent error:

Alpha—0.1 pCi/g

Beta—24 pCi/g

Strontium-90—3.0 pCi/g

Cesium-137—1.5 pCi/g

The variation in the detectable levels is the result of differences in the size of sediment aliquots analysed; i.e., cesium-137, total sample. Each sediment sample represents a surface area of 230 cm².

Mohawk River fish radioactivity

Specimens of Mohawk River fish are collected annually at the Vischer Ferry Dam at the discharge point of the powerhouse effluent. This location is approximately 9,000 feet downstream from the Knolls site sewage outfall.

Samples of the total body are analyzed for gamma radioactivity (cesium-137 equivalent) and samples of the edible tissues are analyzed for strontium-90 content and alpha radioactivity (plutonium-239 equivalent). The specimens, which were all carp, were collected on October 28, 1968.

There were no detectable concentrations of strontium-90 or alpha radioactivity found in the fish samples [minimum detectable concentrations 0.051 pCi/g (100 g sample) for strontium-90, and 0.068 pCi/g (10 g sample) for alpha radioactivities]. The average cesium-137 concentration, based on analysis of the total fish, was 0.095 pCi/g, which is less than the radioactivity level valid at the 90-percent confidence level with an error of 30 percent.

The above results indicate that Knolls operations had no discernible effect upon the radioactivity levels of Mohawk River fish.

Kesselring site

The Kesselring site, located on approximately 4,000 acres near West Milton, N.Y., is a part of the Knolls Atomic Power Laboratory. Its principal facilities include the Triton (S3G) and Bainbridge (D1G) prototype reactors, equipment service building, fuel service building, and waste

treatment facilities. Regular environmental monitoring activities are conducted to verify that laboratory releases of radioactivity to the environment are in compliance with AEC standards.

Air monitoring

Environmental airborne radioactivity is measured at one location at the Kesselring site. Airborne radioactivity is sampled continuously and analyzed on a semiweekly basis. The environmental monitoring station is equipped with a film dosimeter to detect integrated gamma radioactivity levels. The results of the beta-gamma, long-lived radioactivity analyses at the Kesselring site showed an average of 0.12 ± 0.02 pCi/m³. The results were all less than the most restrictive permissible airborne concentration for beta-emitting radionuclides set forth in AEC Manual Chapter 0524.

In addition to the environmental airborne radioactivity monitoring, surveys are made semi-annually of the radiation levels at the Kesselring site perimeter. Perimeter surveys performed during the year showed normal background radiation levels for the geographic location. The result of the perimeter survey extrapolated to an annual exposure indicates average perimeter radiation levels of <0.1 R/a.

Radioactive liquid waste disposal

The liquid waste from the Kesselring site is collected, processed, and sampled prior to release to

the Glowegee Creek. The radioactive waste discharged to the Glowegee Creek in terms of total radioactivity in liquid wastes was 3.7 millicuries for 1968. Radiochemical analyses of these wastes indicated that strontium-89 and strontium-90 concentrations were less than 1 percent of the respective AEC standards for this reporting period. The average result for unidentified radionuclides in the D1G and S3G effluents (19 and 118 pCi/liter) represent less than 1 percent and less than 4 percent, respectively, of the applicable AEC standard (3 nCi/liter).

The average concentrations of beta and gamma radioactivity detected in Glowegee Creek water upstream and downstream from the S3G and D1G liquid-waste outfalls are shown in table 3. All but two Glowegee Creek water analysis results were below 10 pCi/liter which is the measured concentration that may be considered valid at the 90-percent confidence level with a maximum error of 30 percent.

Table 3. Radioactivity in Glowegee Creek water from the Kesselring site operations, KAPL, January-December 1968

Year (1968)	Beta and gamma radioactivity (pCi/liter)	
	Glowegee Creek (upstream)	Glowegee Creek (downstream)
January-March.....	15.0	<3.2
April-June.....	10.0	3.5
July-September.....	5.1	5.1
October-December.....	<8.0	8.0
Calendar year.....	<9.5	<5.0

Water monitoring

Samples of the Glowegee Creek water are analyzed for radioactivity once each quarter year

at two locations, one is about 150 feet above the point where the S3G effluent enters the creek and the other is about 1,500 feet below the D1G effluent discharge point.

Sediment monitoring

Glowegee Creek sediment radioactivity measurements are analyzed on a monthly basis. Sample locations are the same as those listed for Glowegee Creek water sampling. The sediment analysis results are shown in table 4.

General conclusions

As a result of the environmental monitoring program conducted by the Knolls Atomic Power Laboratory, it is concluded that the operation of the Knolls and Kesselring installations did not adversely affect the radioactivity levels of the local environment. The results of the environmental surveys indicate that the levels of radioactivity detected at all times were within the standards established by the U.S. Atomic Energy Commission in the AEC Manual Chapter 0524, "Radiation Protection Standards."

Recent coverage in *Radiological Health Data and Reports*.
 Period: January-December 1967 Issue: February 1969

Table 4. Radioactivity in Glowegee Creek sediment, KAPL, January-December 1968

1968	Location	Number of samples	Gross gamma radioactivity (pCi/g)		Cobalt-60 (pCi/g)
			Average	Range (low/high)	
January-March.....	Upstream.....	2	2.1	0.0 - 6.4	0.13
	Downstream.....	3	2.7	.0 - 4.2	.6
April-June.....	Upstream.....	3	5.6	.42-15.4	3.7
	Downstream.....	3	1.0	.03-2.05	1.2
July-September.....	Upstream.....	3	1.75	1.51-2.23	1.6
	Downstream.....	3	2.30	1.85-2.54	1.9
September-December.....	Upstream.....	^a 1	2.4	2.4 - 2.4	1.9
	Downstream.....	^b 2	2.6	2.19-2.95	1.9

^a No sample taken in December as creek bottom was frozen.

^b Sample data not available for October—malfunction of required counting room equipment.

2. Portsmouth Area Gaseous Diffusion Plant¹ July-December 1969

Goodyear Atomic Corporation
Piketon, Ohio

The separation of uranium isotopes by the gaseous diffusion process presents control problems similar to any chemical process using toxic solvents and extraction solutions. Natural uranium and thorium-234 are the most likely radionuclides to be released to the environment by the Portsmouth Area Gaseous Diffusion Plant. To verify the effectiveness of plant controls, environmental monitoring is conducted for evidence of alpha-particle, beta-particle, and gamma-ray emitters.

Air samples are collected monthly at 21 sites located from 1 to 6 miles from the plant as shown in figure 2. Monthly water samples are collected at 13 stations within 5 miles of the plant.

For July-December 1969, the alpha radioactivity in water, alpha and beta-gamma radio-

activity in air, and background exposure increased over the first half of 1969 values. The beta-gamma radioactivity in water for the July-December period decreased compared with the January-June values.



Figure 2. Sampling locations, Portsmouth Area Gaseous Diffusion Plant

¹Data summarized from B. Kalman and S. H. Hulett, "Environmental Radiation Levels and Concentrations, Second Half 1969" (March 6, 1970).

Table 5. Radioactivity in air, Portsmouth Plant, July-December 1969

Location	Number of samples	Alpha radioactivity concentration (pCi/m ³)			Average as a percent of AEC standards ^a	Beta-gamma radioactivity concentration (pCi/l ²)			Average as a percent of AEC standards ^a
		High	Low	Average		High	Low	Average	
2	6	0.4	<0.1	0.1	5	1.0	<0.1	0.4	0.04
3	6	.9	<.1	.2	10	1.4	<.1	.6	.06
4	6	.3	<.1	.1	5	1.2	<.1	.6	.06
6	6	.9	<.1	.2	10	1.2	<.1	.4	.04
9	6	.1	<.1	<.1	<5	1.7	<.1	.4	.04
12	6	.6	<.1	.2	10	.8	<.1	.5	.05
13	6	.4	<.1	.1	5	.9	<.1	.3	.03
15	6	.2	<.1	<.1	<5	.8	<.1	.5	.05
16	5	.8	.2	.4	20	2.0	.2	.9	.09
17	5	1.3	<.1	.3	15	1.4	.2	.6	.06
18	5	.1	<.1	<.1	<5	1.1	<.1	.3	.03
19	5	.1	<.1	<.1	<5	.8	<.1	.2	.02
20	6	.6	<.1	.2	10	.6	<.1	.3	.03
21	6	1.4	<.1	.3	15	2.5	<.1	.6	.06
22	5	.2	<.1	.1	5	.5	<.1	.3	.03
23	6	.3	<.1	<.1	<5	.4	<.1	<.1	<.01
24	6	.4	<.1	.1	5	1.0	<.1	.2	.03
25	6	.2	<.1	<.1	<5	.6	<.1	.2	.02
26	6	2.4	.3	.8	40	2.4	<.1	1.1	.11
27	5	1.2	<.1	.5	25	2.5	<.1	.9	.09
28	6	1.4	<.1	.6	30	2.1	<.1	.8	.08
Average	120	2.4	<0.1	0.2	10	2.5	<0.1	0.5	0.05

^aThe AEC radiation protection standard for alpha radioactivity in air—2 pCi/m³, beta-gamma radioactivity—1 nCi/m³; sensitivity of analysis of both alpha and beta radioactivity is 0.01 mrem/h.

Table 6. Radioactivity in water, Portsmouth Plant, July-December 1969

Location	Number of samples	Alpha radioactivity concentration (pCi/m ³)			Average as a percent of AEC standards ^a	Beta-gamma radioactivity concentration (pCi/m ³)			Average as a percent of AEC standards ^a
		High	Low	Average		High	Low	Average	
1	6	5.0	<0.5	4.2	0.02	<14.0	<14.0	<14.0	<0.07
2	6	4.5	1.4	3.0	.02	31.5	<14.0	<14.0	<.07
3	6	2.7	.5	.9	<.01	<14.0	<14.0	<14.0	<.07
4	6	3.2	.5	1.0	<.01	<14.0	<14.0	<14.0	<.07
5	6	18.0	.5	3.6	.02	45.0	<14.0	<14.0	<.07
6	6	4.5	.5	2.5	.01	31.5	<14.0	<14.0	<.07
7	6	230	76.5	144	.72	522	22.5	206	1.03
8	6	288	90.0	146	.73	261	<14.0	163	.82
9	6	104	.5	18.0	.09	410	<14.0	72.9	.36
10	6	369	18.0	195	.98	599	54.0	220	1.10
11	6	2.7	<.5	1.0	<.01	36.0	<14.0	<14.0	<.07
12	6	126	18.0	50.9	.25	202	<14.0	82.4	.41
13	6	13.5	.5	6.3	.03	54.0	<14.0	14.9	.07
Average	78	369	0.5	44.4	0.22	598	<14.0	58.4	0.29

^a The AEC radiation protection standard for alpha and beta radioactivity in water—20 nCi/liter; sensitivity of analysis, alpha radioactivity—0.5 pCi/liter; beta radioactivity—14.0 pCi/liter.

Table 7. Background exposure rates, Portsmouth Plant, July-December 1969

Location	Number of samples	Background rate ^a (μrem/h)			Background average rate extrapolated to 3-foot level (μrem/h)	Average as percentage of dose limit rate ^b
		High	Low	Average		
2	6	14.0	11.7	12.7	8.5	14.9
3	6	12.9	9.3	11.7	7.8	13.7
4	6	14.0	11.2	12.3	8.2	14.4
5	6	15.7	10.9	13.5	9.0	15.8
9	6	20.7	12.1	14.2	9.5	16.6
12	6	14.8	11.2	12.4	8.3	14.5
13	6	13.3	10.9	12.1	8.1	14.2
15	6	14.5	10.2	11.6	7.7	13.4
16	6	14.0	11.7	12.3	8.2	14.4
17	6	16.2	10.5	13.4	8.9	15.6
18	6	12.6	10.0	11.1	7.4	13.0
19	6	13.6	11.4	12.2	8.1	14.2
20	6	16.2	11.9	14.2	9.5	16.6
21	6	20.9	11.2	14.5	9.7	17.0
22	6	14.3	10.4	12.3	8.2	14.4
23	6	15.2	11.4	13.2	8.8	15.4
24	6	14.0	11.9	13.1	8.7	15.2
25	6	15.9	10.5	12.5	8.3	14.5
26	6	14.0	10.7	12.4	8.3	14.5
27	6	15.0	12.4	14.0	9.3	16.3
28	6	15.5	10.7	12.2	8.1	14.2
Average	126	20.9	9.3	12.8	8.5	14.9

^a Opt. shield geiger tube one foot above ground.

^b The AEC radiation protection standard for external beta-gamma radioactivity—0.5 rem/a (approx. 600 μrad/h) limit of sensitivity—0.1 μrem/h.

Penetrating background dose rates for 1969 were slightly lower when compared with the calendar year 1968 values. In the calibrations, it is assumed that all of the dose rates are attributable to plant operations. As in the past, the offsite and onsite patterns are very much alike in form and intensity with no significant differences between the average values. From the onsite and offsite intensities, it is evident that the plant operations have not added appreciably to the general background radiation.

Average alpha and beta-gamma radioactivity concentrations in air are summarized in table 5. Table 6 contains the average alpha and beta-gamma radioactivity concentrations in water. The external gamma-ray levels, measured at the air

Table 8. Comparison of average concentrations Portsmouth, 1969

Type of monitoring	Percent of AEC standards ^a			
	Calendar year 1968	January-June 1969	July-December 1969	Calendar year 1969
Air:				
Alpha radioactivity	<5.0	<5.0	^b 10.1	5.7
Beta-gamma radioactivity	0.02	.02	.05	.03
Water:				
Alpha radioactivity	.28	^c .20	.22	.20
Beta-gamma radioactivity	.43	.38	.20	.32
Background exposure extrapolated to 3 feet above ground level				
	18.3	13.5	14.9	14.3

^a See footnote (a) of tables 5 and 6, footnote (b) of table 7.

^b This value was influenced by three high values in August, however, all values were considerably below the AEC standards. There is no explanation for the high result.

^c This value was erroneously reported as 0.02 in the previous report.

sampling locations shown in figure 2, are summarized in table 7. The overall average concentrations and background exposure rates for 1968 and January-June 1969 and July-December 1969 are presented in table 8 as percent of standards.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
July-December 1968	November 1969
January-June 1969	April 1970

Reported Nuclear Detonations, September 1970

(Includes seismic signals from foreign test areas)

The U.S. Atomic Energy Commission announced that on September 6, 1970 the United States recorded seismic signals, presumably from a Soviet underground nuclear explosion. The signals originated at about 2400 e.d.t., September 5, from the Semipalatinsk nuclear test area and were equivalent to those of an underground nuclear explosion in the yield range of 20-200 kilotons.

Errata

In the June 1970 issue of *Radiological Health Data and Reports* the following typographical errors occurred in the article "Zirconium-95 in Utah Vegetation Produced During the 1966 Growing Season":

1. page 279, column 2, 11th line—should read "and milk from farms which showed. . ."
2. page 279, column 2, 14th line—should read "... vegetation during the time should have *been* indicated by sharply . . ."
3. page 280, column 1, 2nd line—"reference 12" should be "reference 11."

Editors note: After publication of this article it was discovered that two announced nuclear tests had been omitted from table 1, page 278. Both tests were detonated on June 15, 1966 at the Nevada Test Site. One test had a yield of 20-200 kilotons. The second test had a yield of less than 20 kilotons and was reported to have vented with minor levels of radioactivity being detected offsite.

In the August 1970 issue an error occurred in table 3 of the article entitled "Disposal of Radioactive Waste from U.S. Naval Nuclear-powered Ships and Their Support Facilities, 1969." Please make the following corrections in table 3 on page 376:

Facility	Number of samples with concentration of cobalt-60:
	>100 pCi/cm ³
Pearl Harbor, Hawaii; Naval Shipyard and base. Apra Harbor, Guam.....	1 0

SYNOPSIS

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

SOME MEASUREMENTS ON RADIOACTIVITY IN SWEDEN CAUSED BY NUCLEAR TEST EXPLOSIONS. *Atilio Magi, Jan Olof Snihs, and Gun Astri Svedjemark. Radiological Health Data and Reports, Vol. 11, October 1970, pp. 487-509.*

Data on environmental radioactivity levels in Sweden during the period 1959-1968 are summarized. Emphasis is placed on gamma radiation from the ground and concentrations of cesium-137 and strontium-90 in some foodstuffs of special interest, such as dairy milk and reindeer meat. Various empirical correlations between the concentrations of radioactivity in milk and meat and those found in precipitation are discussed; such correlations may be used in planning environmental sampling programs. The radiation dose contribution to the population due to fallout is assessed.

KEYWORDS: Body burdens, calcium, cesium-137, fallout, milk, potassium, precipitation, radioactivity, reindeer, strontium-90, Sweden.

ENVIRONMENTAL SURVEY OF URANIUM MILL TAILINGS PILE, MONUMENT VALLEY, ARIZ. *Robert N. Snelling. Radiological Health Data and Reports, Vol. 11, October 1970, pp. 511-517.*

At the request of the Navajo Tribal Council through the Public Health Service Division of Indian Health at Window Rock, Ariz., an environmental radiological survey was conducted on the Foote Mineral Company's uranium tailings pile, Monument Valley, Ariz., in May 1968. The purpose of the survey was to identify any radiation hazards which might exist and recommend methods for their control. The survey included evaluation of external gamma radiation, airborne radioactivity, and waterborne radioactivity.

The results of the survey indicate that existing radiation levels do not exceed recommended exposure limits. However, to minimize the possibility of increased activity from weather conditions different from those existing during the survey, it was recommended that the mill tailings be stabilized against wind erosion. Otherwise, periodic monitoring will be necessary in the future.

KEYWORDS: Air, Arizona, environmental survey, exposure limits, gamma radiation, mill tailings, uranium, water.

RESULTS OF A STUDY OF COLOR TELEVISION SET ASSEMBLY AND REPAIR WORKERS X-RAY SAFETY: *Stanley D. Savic. Radiological Health Data and Reports, Vol. 11, October 1970, pp. 519-525.*

A study was conducted to determine the degree of exposure of television set assemblers and repairmen to low levels of low energy x radiation. Two independent companies supplied the x-ray film badges on a biweekly basis. In addition, some television repairmen were also asked to wear thermoluminescent (TLD) ring badges so that the degree of hand exposure to x rays could be determined. In two large service shops, detailed records were also kept of the number and models of television receivers which were serviced. The largest total exposure recorded by film badges worn by any repairman during the one and a half year duration of the survey, was 34 mR. During that same time, no other badge showed any radiation, and therefore we assume that this one film was inadvertently exposed to heat or some other element. In a later survey, there were a few scattered hand exposure readings ranging from 10 to 70 mR for TLD rings which were continuously worn over a 3-month period. These readings were also suspected to be false because they were not repeatable with the same individuals and because hundreds of other TLD rings registered no dosage. During the 8-months duration of the factory assemblers' survey, over half a million color television receivers were produced by the 1,000 monitored employees. Not a single film badge worn in the factory assemblers' survey showed any radiation. We conclude that occupational x-radiation exposure of television repairmen and assemblers is virtually nonexistent.

KEYWORDS: Color television, film badges, hand exposure, safety, TV repairmen, TV set assemblers, x radiation.

SYNOPSIS

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

ELEVATED LEVELS OF CESIUM-137 IN COMMON MUSHROOMS (*Agaricaceae*) WITH POSSIBLE RELATIONSHIP TO HIGH LEVELS OF CESIUM-37 IN WHITETAIL DEER, 1968-1969. Wallace Johnson and Chester L. Nayfield. Radiological Health Data Reports, Vol. 11, October 1970, pp. 527-531.

High levels of cesium-137 exist in game animals of the southeastern United States. The highest levels ranging from 250 to 152,940 picocuries per kilogram have been found in muscle tissue of the Whitetail deer. Levels in Florida range from 10 to 100 times those encountered in Alabama. An important factor in the diet of these animals in Florida is the common gill mushroom, *Agaricaceae*. Examination of these fungi revealed cesium-137 levels higher by an order of magnitude than levels in vegetation. Similar concentrations of potassium-40 do not occur, indicating a selective effect.

KEYWORDS: *Agaricaceae*, cesium-137, deer, Florida, game animals, mushrooms

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 11, Number 11, November 1970

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Bureau of Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

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CONTENTS

Page

REPORTS

- Analysis of Iodine-131 in Bovine Thyroids,
October 1964 through February 1969..... 573

John L. Russell and Gerald A. Pliner

- Results of 33,911 X-ray Protection Surveys of
Facilities with Medical or Dental Diagnostic
X-ray Equipment, Fiscal Years 1961-1968..... 581

*Lawrence R. Fess, Richard B. McDowell
Wayne R. Jameson and Ray W. Alcox*

TECHNICAL NOTES

- Preliminary Survey of X-ray Producing Devices
in Kansas Schools, 1968..... 613

Leo W. Spencer, Jr.

DATA

- SECTION I. MILK AND FOOD..... 617

- Milk Surveillance, July 1970..... 617

- Food and Diet Surveillance..... 628

1. Estimated Daily Intake of Radionuclides in
California Diets, April-December and January-
June 1970..... 628

2. Radionuclides in Institutional Diet Samples,
January-March 1970..... 633

CONTENTS—continued

RADIOLOGICAL HEALTH DATA AND REPORTS

	Page
SECTION II. WATER.....	637
Tritium in Surface Water Network, January-June 1970, PHS.....	638
SECTION III. AIR AND DEPOSITION.....	641
Radioactivity in Airborne Particulates and Precipitation.....	641
1. Radiation Alert Network, July 1970, PHS.....	642
2. Canadian Air and Precipitation Monitoring Program, July 1970.....	645
3. Mexican Air Monitoring Program, July 1970.....	646
4. Pan American Air Sampling Program, July 1970, PAHO and PHS.....	647
SECTION IV. OTHER DATA.....	649
Environmental Levels of Radioactivity at Atomic Energy Commission Installations.....	649
1. Lawrence Radiation Laboratory, July- December 1969.....	649
2. Shippingport Atomic Power Station, January-December 1969.....	655
Reported Nuclear Detonations, October 1970.....	658
Synopses.....	iii
Guide for Authors.....	Inside back cover

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service
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Reports

Analysis of Iodine-131 Data in Bovine Thyroids, October 1964 Through February 1969

John L. Russell and Gerald A. Pliner¹

A detailed analysis of the bovine thyroid data from October 1964 through February 1969, as reported in *Radiological Health Data and Reports*, shows that most positive results can be related to various nuclear tests with known atmospheric intrusions. The widespread nature of various samples having positive concentrations of short-lived fission products and the rapid increase of levels in these samples indicate the source to be a major atmospheric intrusion.

Estimates determining thyroid dose in man from iodine-131 concentrations in bovine thyroids appear to be feasible under selected conditions but are of little use in evaluating nationwide network data. The lower limit of detectability is 1 pCi ¹³¹I/g bovine thyroid, and most samples at this level have a 2-standard deviation error greater than the measured quantity.

The Bureau of Radiological Health (BRH), Environmental Health Service, has operated a national program for the collection and analysis of iodine-131 in bovine thyroids since October 1964. This program, known as the Bovine Thyroid Network, has been described in *Radiological Health Data and Reports (RHD&R) (1)*. The program was based on pilot studies by the BRH (2-3) and on the work performed by other investigators. Data from the network was routinely published in the above reference. Because levels of radioactivity detected in this network were very low, the project was discontinued on March 1, 1969.

A review of the bovine thyroid data through 1965 was presented by Baratta (4). Since this review, a number of atmospheric nuclear tests have been conducted providing additional information for the evaluation of bovine thyroids as an environmental sampling tool. This paper attempts to evaluate the data for the period that the Bovine Thyroid Network was a routine operational program.

Data evaluation

Several factors contribute to the concentrations of iodine-131 in bovine thyroids and to the rela-

tive percent of thyroids having measurable concentrations during a fresh fission product contaminating event. Some of these factors are:

1. type and size of contaminating event,
2. distance from contaminating event and meteorological conditions,
3. feeding patterns (includes many variables),
4. age of animal,
5. whether lactating or not,
6. whether diseased or not, and
7. collection time after event.

All of these variables contribute to the wide range of concentrations found during a given period. Blincoe et al. (5) found wide ranges of concentrations for localized herds in Nevada under controlled conditions. Data collected on a nationwide basis would then be expected to show wider variations.

Sensitivity and reporting levels

Measurement of very low concentrations of iodine-131 in bovine thyroids is difficult due to the interference of other radioactive nuclides in the thyroid. Van Middlesworth (6) has reported the presence of radium-226 and another unidentified long-lived radionuclide in the thyroid, both of which can be mistakenly identified as iodine-131. The Bovine Thyroid Network routinely reported levels of 1 pCi/g or less as ND (nondetectable) or 0 to allow for possible interference.

¹ Mr. Russell and Mr. Pliner are nuclear engineers in the Nuclear Facilities Branch, Division of Environmental Radiation, Bureau of Radiological Health, 1901 Chapman Avenue, Rockville, Md. 20852.

It must be emphasized here that the 1 pCi/g sensitivity limit applies only to the routine measurement of bovine thyroids on a large scale where 10 percent of the results (4) were verified with a second count. Various investigators (5,7) have approached a 0.1 pCi/g sensitivity limit by employing sophisticated counting techniques.

The physiological accumulation of iodine-131 in the thyroid made the Bovine Thyroid Network a sensitive indicator of atmospheric intrusions of fresh fission products. Based on a study in which iodine-131 was administered orally to two Holstein cows, Harris (8) reported the ratio of iodine-131 in bovine thyroids in pCi/g to the iodine-131 in milk in pCi/liter to be ≥ 10 from the 2d day to the 19th day after administration and to reach a maximum of about 18 for the 5th through the 9th day. Other investigators (9,10) have found this ratio to be 12 and 14, respectively. Extensive controlled environmental radioiodine tests (11) also support these ratios. The practical reporting level for bovine thyroids is about 1 pCi/g and for milk is about 10 pCi/liter. The bovine thyroid is then about two orders of magnitude more sensitive than milk in reflecting the presence of iodine-131 in the atmosphere. Harris (8) reached this same conclusion in his presentation.

In his earlier paper on the Bovine Thyroid Network, Baratta (4) reports an overall sensitivity improvement of 30 for bovine thyroids to milk. This conclusion was based on a ratio of 3 for pCi ^{131}I /g thyroid to pCi ^{131}I /liter milk. However, this conclusion is subject to all the uncertainties listed previously, and in one of his examples (South Dakota), the ratio exceeded 10.

Estimation of human thyroid dose from iodine-131 concentrations in bovine thyroids

Because of the relatively high sensitivity, bovine thyroid data can be used to estimate the dose to the human thyroid when concentrations in milk are below 10 pCi ^{131}I /liter, i.e., Range I of FRC Guidance (12). This dose estimate could be used for a single contaminating event if the time of contamination is known or for a continuous contaminating situation where iodine-131 is being deposited on the pasture at a constant rate for a period necessary to achieve equilibrium. The dose estimate is made by using the bovine thyroid to milk ratio discussed here, assuming all human

intake is from milk, and using FRC guidance (12) for average daily intake or for a single contaminating event. The assumption that all iodine-131 intake is from milk is valid according to Soldat (13), especially for children where fresh vegetable intake is small.

For the continuous situation, if the constant level of iodine-131 in bovine thyroids is 12 pCi/g, the milk concentration would be 1 pCi/liter and the dose would be 5 mrem/a to the child's thyroid. In the case of a single contaminating event and a maximum value of 120 pCi/g bovine thyroid, the maximum concentration in milk would be 10 pCi/liter and the dose commitment to the child's 2-gram thyroid would be 1.2 mrad (14).

Applying the constant level dose estimation method to the bovine thyroid data reported here is not valid as is evident from figure 1 where concentrations vary by 3 orders of magnitude. The dose probably could be estimated for a single milkshed using the single event method if sufficient data were available for that particular area. However, the results would be subject again to all the uncertainties previously listed.

Analysis

The bovine thyroid data collected by the Bovine Thyroid Network were analyzed for the period October 1964 through February 1969. Table 1 summarizes the results. Positive samples are those for which concentrations were reported. Negative data are reported as "ND" or "0" and indicate that the 2-sigma counting error was greater than the concentration measured. Samples measuring 1 pCi/g or more were used in calculating the percent of positive samples. Also included in this table are nuclear test shots reported in RHD&R and nuclear rocket tests which were conducted at the Nevada Test Site (NTS) during May, June, and July 1962.² The data presented in RHD&R are grouped into 3- and 6-month reporting periods. Interpretation in this format was not possible because iodine-131 has a residence time in the environment of only 2 to 3 months. Thus, the original data were analyzed for monthly periods and the average and maximum values were plotted (figure 1). The percent of positive

² Verbal communication from Mr. Frank Grossman, Southwestern Radiological Health Laboratory (SWRHL), Public Health Service, Las Vegas, Nev., October 21, 1969.

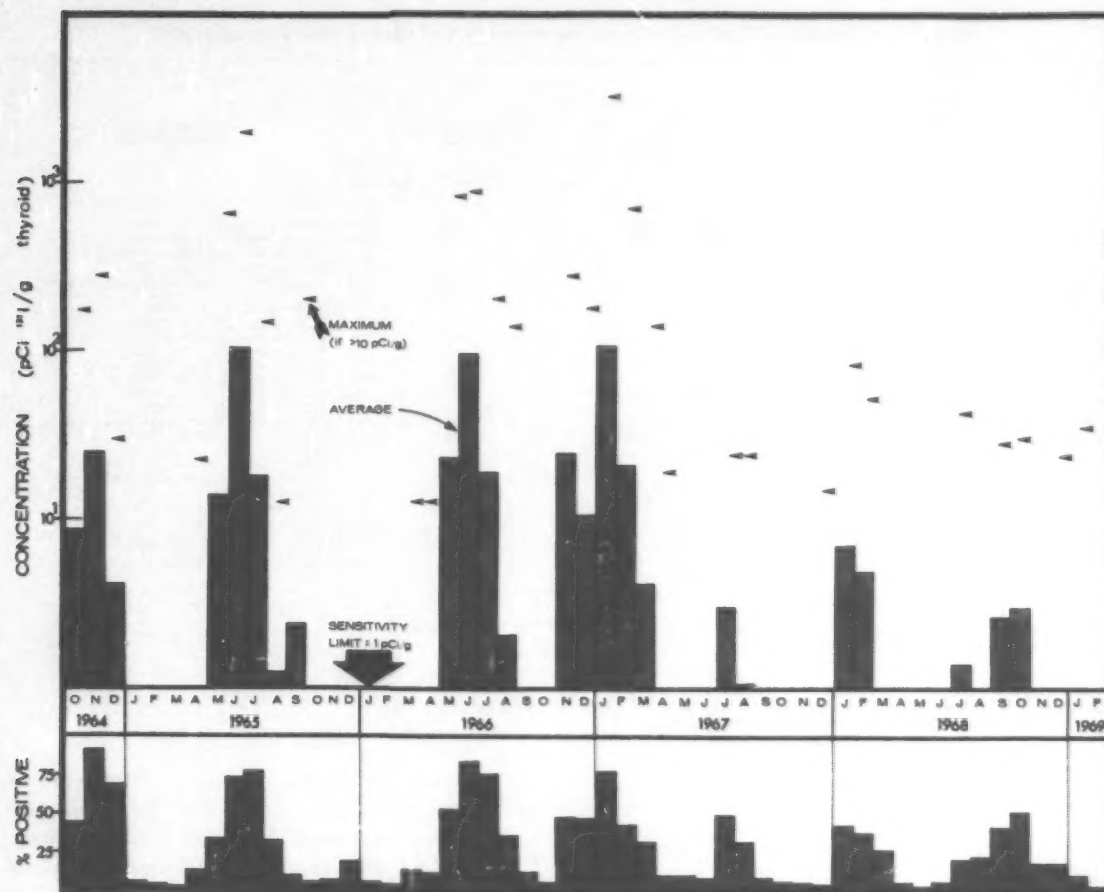


Figure 1. Summary of Bovine Thyroid Network, October 1964–February 1969 Monthly averages, maximums, and percent of positive samples

samples for each month is also shown on figure 1. The sudden and large increases in iodine-131 concentrations in bovine thyroids following atmospheric nuclear tests are readily discernible in the plot. To show the close relationship of positive bovine thyroid samples and major atmospheric intrusions of fresh fission products, a chronological list is helpful (table 2).

The transport time for fresh fission product debris from the Chinese mainland to the conterminous United States has been reported to be 3–5 days (15,16). The buildup time in the thyroid, after deposition on pasture, varies considerably (11) but can be as short as 1 to 2 days. Positive bovine thyroid samples could then be expected in 4 or 5 days after a test on the Chinese main-

land. The shortest observed time difference here is 9 days for three different tests and the longest time lag is 18 days for one test. The predominant cause of this variability was the lack of a routine sampling schedule. Most samples were obtained from positive reactors to brucellosis and tuberculosis tests which frequently resulted in sporadic slaughter dates. The geographical coverage also influenced the time factor since many areas of the country did not participate in the program or participated minimally. Other factors which influenced this time lag were discussed in a prior section. Consequently, the Bovine Thyroid Network did not provide an effective alert mechanism for the intrusion of fresh fission products into the atmosphere.

Table 1. Summary of iodine-131 in bovine thyroids for October 1964–February 1969

Period	RHD&R issue	Number of samples	Summary of data				Reported tests (from RHD&R)
			Percent positive	Concentration (pCi/g)			
				Average	Minimum	Maximum	
Oct-Dec 64	Oct. 65 (p. 566)	294	60	13	ND	280	Foreign test, Oct. 16, 1964
Jan-June 65	Jan. 66 (p. 49)	1,250	24	19	ND	1,070	Foreign vent, Jan. 15, 1965 NTS excavation, Apr. 14, 1965 Foreign test, May 14, 1965
July-Dec 65	Oct. 66 (p. 601)	1,614	22.6	3.5	ND	206	No atmospheric intrusion tests reported
Jan-June 66	Jan. 67 (p. 51)	1,747	33.3	19	ND	883	NTS vent, Mar. 5, 1966 NTS vent, Apr. 25, 1966 Foreign test, May 9, 1966
July-Dec 66	Apr. 67 (p. 227)	2,401	35.2	9.2	ND	279	Foreign test, July 2, 1966 Foreign test, July 19, 1966 Foreign test, Oct. 27, 1966
Jan-Mar 67	Aug. 67 (p. 465)	1,020	50.1	42	ND	3,280	Foreign test, Dec. 28, 1966
Apr-Sept 67	Feb. 68 (p. 120)	1,356	16.3	<1	ND	22	Foreign test, June 17, 1967
Oct-Dec 67	May 68 (p. 280)	676	3.6	<1	ND	13	NTS vent, June 29, 1967
Jan-Mar 68	Aug. 68 (p. 456)	516	33.7	3.7	ND	83	No atmospheric intrusion tests reported Foreign test, Dec. 24, 1967 NTS vent, Jan. 18, 1968
Apr-June 68	Nov. 68 (p. 695)	518	3.3	<1	ND	7	NTS excavation, Jan. 26, 1968
July-Sept 68	Feb. 69 (p. 77)	862	26.1	1.3	ND	44	NTS excavation, Mar. 12, 1968 a Nuclear rocket tests-NTS a Nuclear rocket tests-NTS
Oct-Dec 68	Apr. 69 (p. 178)	796	28.3	1.3	0	31	NTS excavation experiments NTS excavation, Dec. 8, 1968
Jan-Feb 69	Nov. 69 (p. 523)	445	5.1	<1	0	36	Foreign test, Dec. 27, 1968 No atmospheric intrusion tests reported.

a Not reported in RHD&R, see text.

b Beginning July 1968, concentrations of 1 pCi/g or less (previously reported as ND) are reported as 0. ND, nondetectable.

Table 2. First positive bovine thyroid samples following major atmospheric intrusions of fresh fission products

Atmospheric nuclear test		First positive bovine thyroid sample		
Date	Location	Date	Concentration (pCi/g)	Location (County, State)
10/16/64	Chinese mainland	10/20/64	174	Erie, N.Y.
5/14/65	Chinese mainland	5/25/65	29	San Luis Obispo, Calif.
5/9/66	Chinese mainland	5/18/66	17	Los Angeles, Calif.
10/27/66	Chinese mainland	11/8/66	100	Knox, Tenn.
12/28/66	Chinese mainland	1/6/67	271	Anderson, Kans.
6/17/67	Chinese mainland	7/5/67	9	Loudon, Tenn.
12/24/67	Chinese mainland	1/2/68	8	Lumpkin, Ga.

Figure 1 also illustrates the 2- to 3-month residence time of iodine-131 in the environment following a major intrusion of fresh fission products. This residence time agrees with 10 physical half-lives or 10 pasture half-times (17). In addition to the increases caused by atmospheric testing of nuclear devices, there were 4 months in the absence of testing when the network average was above 1 pCi/g. These periods were September 1965, July 1968, and September–October 1968. Each of these periods is considered separately.

September 1965

The average concentration of iodine-131 in bovine thyroids was 2.4 pCi/g for September 1965. Increased levels from the Chinese mainland test of May 14, 1965, had disappeared by the middle of August 1965. This higher average resulted from four samples collected in the central valley of California on September 13 and 14, 1965 (table 3). Of the total of 72 samples collected in California from September 7 through September 21, 1965, the results of 66 samples were nondetectable; one measured 3 pCi/g; another, 5 pCi/g; and the remaining four are listed in table 3. Of the 13 samples collected from Merced County during this period, 11 were nondetectable. One of six was positive for Fresno County, one of eight was positive for San Joaquin County, and both samples from Santa Clara County were positive.

During a major intrusion of fresh fission products, bovine thyroid samples from a given area are generally all positive, though concentrations can vary considerably. The data from California for September 1965 did not follow this pattern since less than 10 percent (i.e., 6 from a total of 72) were positive and concentrations of only four positive samples were relatively large. Feeding

**Table 3. Iodine-131 concentrations in bovine thyroids
September 1965**

Date (1965)	County	Iodine-131 concentration (pCi/g)
9/13.....	Fresno.....	179
9/13.....	Merced.....	206
9/13.....	San Joaquin.....	55
9/14.....	Santa Clara.....	186

patterns could account for this unusual situation, especially in the early fall. The positive concentrations are quite likely valid since iodine-131 was found in milk over a wide area at this time. Iodine-131 was reported (18) in milk samples from Denver, Colo., St. Louis, Mo., Albuquerque, N. Mex., Portland, Oreg., and Seattle, Wash., during September 1965. Baratta (4) observed a coincident sudden increase of iodine-131 from one of the western United States nuclear installations during this same period. The radiological status report on the Hanford environs for September 1965 (19) states, "The concentrations of iodine-131 measured in beef thyroids were generally less than 10 pCi/g. The slightly higher concentrations noted for Pasco samples (25 pCi/g maximum) may be attributable to a slightly above normal release of iodine-131 in early September from the laboratory facilities." It appears that the iodine-131 found in bovine thyroids and milk during this period came from the Hanford facilities.

July 1968

The average concentration of iodine-131 in 287 bovine thyroid samples for July 1968 was 1.34 pCi/g. There were no major tests reported during this period; however, there were a number of nuclear rocket engine tests conducted at the Nevada Test Site (NTS) during this period. The largest reactor engine tested was the Phoebe-2A which was run at various power levels on May 29, June 8 and 26, and July 18, 1968.² Since this reactor engine was run under different conditions than the Phoebe-1B runs (20), it was estimated that the release of iodine-131 during the Phoebe-2A runs amounted to some hundreds of curies.³ These runs were performed with the exhaust upward, and the effective plume height would be on the order of 1,000 to 10,000 feet resulting in dis-

² Personal communication from Mr. John J. Lane, Space Nuclear Propulsion Office, Atomic Energy Commission.

persion by prevailing winds. Most of the positive samples for July 1968 were collected in Colorado, South Dakota, and Wyoming. Other positive samples were near the sensitivity limit (see discussion on sensitivity and reporting levels) and widely scattered. These positive results from Colorado and South Dakota cannot be attributed to nuclear power reactors since there are none in this area. The Elk River plant in central Minnesota, and Pathfinder located in South Dakota, were shut-down during this period (21). There were no nuclear power plants operating in Colorado or any State adjacent to Colorado. Therefore, the nuclear rocket tests at NTS were probably the source of iodine-131 during this period.

September-October 1968

During September 1968, there appeared to be a major intrusion of iodine-131 into the atmosphere. The average concentration for September was 2.6 pCi/g and nearly 40 percent of all samples were positive, indicating widespread contamination. The average concentration was 2.9 pCi/g in October 1968 and the number of positive samples increased to 50 percent of all samples collected. In contrast, the number of positive samples for July 1968 was 19 percent of the total. The maximum concentration in July 1968 was 44 pCi/g; however, the maximum concentrations reached only 29 pCi/g in September 1968 and 31 pCi/g in October 1968. The source of iodine-131 causing these widespread positive concentrations could not be found in the available literature; however, a series of nuclear tests were conducted in the South Pacific during this period.

Discussion

While the Bovine Thyroid Network proved to be a sensitive indicator of iodine-131 in the atmosphere, it did not serve adequately as an alert mechanism. Several of the many variables affecting the concentration of iodine-131 in bovine thyroids contributed to this failure. The most important factor contributing to this inadequacy is that iodine apparently does not build up in the thyroid as quickly as in milk (8,11).

The network gave additional documentation of fallout levels as determined by other surveillance programs, especially the Pasteurized Milk

Network. It appeared to reflect the selective release of iodine-131 during September 1965 when air filter sampling failed to show an increase in environmental levels. Bovine thyroid sampling also proved useful in documenting situations where iodine-131 levels were low and below the detection limit in milk as during the summer and fall of 1968.

The use of bovine thyroids for routine surveillance of nuclear facilities does not appear to be feasible in spite of their high sensitivity (~ 1.0 pCi/g). Federal regulations restrict the discharge of iodine-131 from nuclear power installations because of its rapid assimilation into the food chain. If the small quantities of iodine-131 routinely discharged from nuclear power plants were sufficient to produce measurable concentrations in bovine thyroids, a relatively constant level of iodine-131 in bovine thyroids would be expected. This effect has not been observed. Bovine thyroid concentrations were below minimum detectable limits for all periods in which there were no atmospheric intrusions with the exception of the fall of 1968. Kahn (?) reported low concentrations (≤ 0.5 pCi/g) of iodine-131 in bovine thyroids in his study of Dresden. However, he was unable to definitely establish the source of this iodine. If Dresden Nuclear Power Station is assumed to be the source of the iodine-131, the Bovine Thyroid Network, as previously operated, would not be sufficiently sensitive to measure levels caused by the nuclear installation.

Estimation of dose of the human thyroid using bovine thyroid data from a national network is of questionable validity. Under controlled conditions human thyroid doses could quite probably be estimated with accuracy, although analysis of the milk would be preferred since milk is the major intake contributor.

Summary

A detailed analysis of the bovine thyroid data from October 1964 through February 1969, as reported in *RHD&R*, shows that most positive results can be related to various nuclear tests with known atmospheric intrusions. The widespread nature of various samples having positive concentrations of short-lived fission products and the rapid increase of levels in these samples indicate the source to be a major atmospheric in-

trusion. Routine, low-level discharges from nuclear power plants would not, in our opinion, give rise to sudden, nationwide increases in radionuclide concentrations.

Estimates determining thyroid dose in man from iodine-131 concentrations in bovine thyroids appear to be feasible under selected conditions but are of little use in evaluating nationwide network data. The lower limit of detectability is 1 pCi ^{131}I /g bovine thyroid and most samples at this level have a 2-standard deviation error greater than the measured quantity.

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Results of 33,911 X-ray Protection Surveys of Facilities with Medical or Dental Diagnostic X-ray Equipment, Fiscal Years 1961-1968

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The results of radiation surveys of 33,911 medical and dental x-ray facilities are presented and analyzed. It was found that a high percentage of x-ray machines in medical facilities have improper collimation and inadequate filtration. In addition, a large proportion of the facilities do not possess adequate accessory patient or operator shielding. The use of an open-end aiming device, high-speed film, and the need to improve darkroom procedures were the primary recommendations made for dental facilities.

Data from x-ray protection surveys of 12,847 medical and 21,064 dental x-ray facilities, conducted by State radiological health personnel in 25 States and two territories, were available (as of June 30, 1968) for analysis by the Bureau of Radiological Health (BRH). These States and territories had programs in various stages of development with respect to regulations and recommendations for x-ray protection and their interpretation. The dental surveys were conducted from fiscal year (FY) 1961-FY 1968; the medical surveys, from FY 1963-FY 1968. The data, collected on standardized forms supplied by the Public Health Service (PHS), (appendix 1, figures 11-18) were analyzed for information from which frequency distributions on selected items of interest were generated. For the medical x-ray protection surveys, the standardized forms used were: Facility Form (PHS 4495-1), Fluoroscopic Form (PHS 4495-2), and Radiographic Form (PHS 4495-3); for dental surveys, form PHS 3657 was used. The medical x-ray forms were revised in July 1965. Those forms printed prior to that date are designated "old forms," and those forms printed after July 1965 are called "new forms." The revision resulted in the deletion, change, or addition of some items to the new form. Where these items occur in the tables, a footnote indicates whether they came from the "old" or "new" forms.

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The frequency distribution tables provide a summation of data from the medical and dental x-ray protection survey report forms. Information is presented by facility category, equipment type and usage, and equipment status as related to the recommendations of the National Committee on Radiation Protection as published in the National Bureau of Standards (NBS) Handbook 76 and workload as related to the type of machine and category of user. For purposes of definition, a facility is an address having one or more x-ray machines, and an x-ray machine consists of an x-ray tube with the necessary appurtenances to permit its use for radiographic and/or fluoroscopic procedures.

The medical radiographic and fluoroscopic examination data are related to the two most usual procedures reported to have been performed on an "average" or "standard" man with the x-ray equipment located in the 12,847 medical facilities. The examination data are presented according to the most frequently reported radiographed and fluoroscoped body areas: chest, abdomen, extremities, and spine for radiography; chest and gastrointestinal tract for fluoroscopy. All remaining types of radiographic examinations are included in the "all other" category. Because of the provision on the radiographic and fluoroscopic survey forms for reporting the two most usual procedures performed on each machine, the number of procedure reports could theoretically be double the number of machines. As expected, however, information about a second procedure on a machine was often lacking. This

occurred more frequently in the case of fluoroscopic machines. Although many of these machines were physically surveyed, no procedure information was obtained because the fluoroscopic capability was not used. Hence, although 4,849 machines with fluoroscopic capability were physically surveyed, there were only 5,388 reports of procedures rather than the 9,698 that were theoretically possible.

Selected highlights

Medical X-ray Protection Surveys

Personnel data by type of facility

The 12,847 medical x-ray facilities are listed by the major types of facility (or practice) in descending order of magnitude of their radiographic workload. The highest workloads are reported for radiologists, hospitals, and multiple specialty clinics. The "all others" category contains specialty groups that were too small in number to permit comparison with the larger practitioner categories in this sample.

As expected, those categories with high workloads ranked high in both average number of personnel occupationally exposed and in average number of x-ray machine operators per facility (table 1). At the same time, it is within these high workload categories that the highest percentage of occupationally exposed persons and machine

operators, who are being monitored for their radiation exposure, are found. However, the data from the facilities with lower workloads suggests the need for closer observation of the operator levels of exposure and possible recommendations of additional personnel monitoring.

Equipment and darkroom data by type of facility

Figures presented in the first section of table 2 indicate that the larger machine-per-facility ratios are found in facilities with greater workloads or where one would expect multiple procedures to be performed. This is also evident, when examining the ratio of x-ray tubes to machines, since the same facilities tend to have multi-tube machines.

Certain facilities in the second section of table 2 are reported to have no darkrooms. This may be explained, in part, by the use of vertical fluoroscopes, some of which require no darkroom facilities, and partially by the increase in the use of automatic processors which the surveyor may not have considered to be in a "darkroom" in the technical sense of the word.

Workload by type of facility

Table 3 presents the workload data that provided the basis for ranking the specialties in the tables appearing in this report.

Table 1. Personnel data by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Personnel characteristics	Type of facility or type of practice										
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners in clinics	General practitioners in private practice	Osteopaths	Chiropractors	Podiatrists	All others	All facilities
Average number of persons occupationally exposed per facility surveyed	4.4	6.5	4.3	2.4	3.2	2.1	1.6	1.2	1.3	2.6	2.8
Average number of x-ray machine operators per facility surveyed	3.8	5.6	3.1	1.7	2.6	1.8	1.5	1.1	1.2	1.0	2.3
Average number of persons monitored per facility surveyed	3.2	5.3	2.2	.3	.8	.3	.1	.1	.1	.6	1.2
Ratio of x-ray machine operators to total persons occupationally exposed	.87	.85	.75	.71	.81	.85	.90	.94	.89	.73	.82
Percent of persons occupationally exposed who are monitored	71.7	80.8	49.6	14.3	23.3	12.3	7.1	9.8	7.8	23.3	41.0
Percent of x-ray machine operators who are monitored	82.4	95.0	66.0	20.2	26.7	14.4	7.9	10.4	8.8	31.8	55.0
Number of facilities	495	1,727	297	749	413	3,119	287	1,718	806	3,206	12,847

**Table 2. Equipment and darkroom data by type of facility
(Medical X-ray Protection Survey Reports, fiscal years 1963-1968)**

Equipment and darkroom characteristics	Type of facility or type of practice									
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners in clinics	General practitioners in private practice	Osteopaths	Chiropractors	Podiatrists	All others
Equipment:										
Average number of x-ray machines per facility surveyed	3.2	3.6	1.8	1.1	1.2	1.0	1.0	1.0	1.0	1.2
Average number of x-ray tubes per facility surveyed	3.8	5.1	2.0	1.2	1.5	1.1	1.1	1.0	1.0	1.3
Ratio of x-ray tubes to machines	1.6	1.3	1.3	1.1	1.3	1.1	1.1	1.0	1.0	1.1
Darkroom:										
Percent of facilities surveyed with no darkroom	3.2	6.4	10.4	34.4	5.8	12.0	5.2	0.5	8.4	14.1
Percent of darkrooms surveyed that were lighttight	83.8	77.7	80.5	67.5	74.8	72.1	87.1	74.8	86.0	78.9
Percent of facilities surveyed with automatic film processing capability	30.6	22.7	8.4	1.6	2.4	2.1	1.0	1.1	3.7	2.0
Number of facilities	486	1,737	297	740	413	3,119	287	1,718	806	3,306

Table 3. Workload data by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Workload characteristics	Type of facility or type of practice									
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners in clinics	General practitioners in private practice	Osteopaths	Chiropractors	Podiatrists	All others
Radiographic exposures:										
Number of facilities reporting	192	840	172	256	358	1,606	133	898	299	1,198
Average per facility per week	48 ^a	421	129	28	63	17	11	8	6	83
Patients radiographed:										
Number of facilities reporting	228	843	116	239	144	1,195	136	791	483	957
Average per facility per week	104	189	114	20	45	14	8	5	4	63
Fluoroscopic examinations:										
Number of facilities reporting	187	729	85	289	107	468	35	19	2	368
Average per facility per week	35	28	12	10	8	8	(a)	(a)	(a)	14
Patients fluoroscoped:										
Number of facilities reporting	222	742	41	195	53	345	13	9	2	212
Average per facility per week	30	33	29	10	5	9	(a)	(a)	(a)	13

- ^a Data available from "old" facility form PH8-4495-1 only.
^b Data available from "new" facility form PH8-4495-1 only.
^c Frequency too small to permit valid calculation.

**Table 4. Distribution of diagnostic x-ray equipment by type of machine
(Medical X-ray Protection Survey Reports, fiscal years 1963-1968)**

X-ray equipment					
Radiographic			Fluoroscopic		
Type	Number	Percent	Type	Number	Percent
Fixed	11,329	77.0	Tilting ^a	3,630	79.0
Mobile	2,906	19.1	Vertical	608	18.7
Photofluorographic	206	1.4	Other ^b	114	2.3
Other	374	2.5	Total	4,349	100.1
Total	14,717	100.0			
Of the total number of radiographic machines, 40.9 percent have fluoroscopic capability			Of the total number of fluoroscopic units, 80.0 percent have radiographic capability		

- ^a Includes horizontal table-type fluoroscopes.
^b Includes coding error, not reported, and undetermined.

Distribution of diagnostic x-ray equipment by type of machine

The distribution of medical radiographic and fluoroscopic equipment by machine type is presented in table 4. The greatest percentage of radiographic machines are classified as fixed, with approximately one-half of the fixed machines (5,586) having fluoroscopic capability.

Radiographic workload per machine by type of facility

Table 5 reflects the workload in terms of radiographic exposures per week, per machine, and patients radiographed per week, per machine. The distributions are similar to those presented in table 3.

Table 5. Radiographic workload per machine by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Radiographic workload per machine	Type of facility or type of practice										
	Radi- ologists	Hospitals	Multiple specialty clinics	Inter- nists	General practi- tioners in clinics	General practi- tioners in private practice	Osteo- paths	Chiro- practors	Podia- trists	All others	All facilities
Radiographic exposures: ^a Number of machines for which radiographic exposures were re- ported.....	353	2,310	215	288	367	1,551	129	884	291	817	7,105
Average per machine per week.....	193	115	95	26	60	17	11	9	7	63	66
Patients radiographed: ^b Number of machines for which patients radiographed were re- ported.....	346	2,674	171	360	148	1,169	136	766	468	654	6,832
Average per machine per week.....	50	50	79	46	34	14	8	5	5	45	35

^a Data available from "old" radiographic form PHS-4405-3 only.
^b Data available from "new" radiographic form PHS-4405-3 only.

Table 6. Distribution of radiographic machines by recommendations as specified in NBS Handbook 76 (1) and by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Recommendations	Type of facility or type of practice										
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners in clinics	General practitioners in private practice	Osteopaths	Chiropractors	Podiatrists	All others	All facilities
Genadal shields for patients: Number of reports..... Percent in compliance.....	697 (75.6)	4,571 (63.9)	360 (68.0)	555 (38.7)	395 (47.8)	2,586 (45.6)	247 (31.6)	1,553 (33.4)	690 (13.4)	1,276 (47.6)	13,039 (50.8)
Filtration not less than 2.5 mm. of aluminum equivalent: Number of reports..... Percent in compliance.....	706 (85.6)	4,864 (71.2)	379 (69.9)	560 (57.0)	407 (53.3)	2,712 (41.5)	267 (35.3)	1,641 (60.1)	736 (27.8)	1,458 (57.8)	13,750 (58.9)
Adequate exposure switch location: Number of reports..... Percent in compliance.....	747 (73.0)	5,137 (83.5)	387 (88.1)	508 (70.0)	423 (92.4)	2,744 (86.4)	364 (89.4)	1,637 (91.3)	768 (68.5)	1,526 (84.6)	14,195 (53.3)
Adequate operator protection: Number of reports..... Percent in compliance.....	719 (98.9)	5,005 (97.5)	387 (96.6)	500 (90.0)	417 (93.8)	2,712 (88.5)	253 (90.5)	1,622 (93.9)	769 (79.1)	1,493 (93.8)	13,967 (93.5)
Adequate primary and secondary barrier: Number of reports..... Percent in compliance.....	703 (98.6)	4,300 (96.0)	381 (94.2)	578 (90.5)	413 (92.7)	2,686 (92.0)	256 (94.9)	1,617 (96.8)	767 (85.2)	1,444 (94.2)	13,144 (94.6)
Deadman type switches: Number of reports..... Percent in compliance.....	364 (97.8)	2,317 (99.0)	219 (98.6)	293 (100.0)	273 (99.0)	1,578 (96.6)	133 (100.0)	892 (91.7)	297 (99.3)	831 (97.1)	7,214 (98.0)
Diagnostic type tube housing: Number of reports..... Percent in compliance.....	650 (99.2)	4,279 (98.8)	306 (100.0)	515 (96.5)	336 (99.1)	2,430 (98.3)	183 (97.8)	1,310 (97.5)	749 (98.9)	1,374 (98.4)	12,313 (98.5)
Timer termination exposure: ^a Number of reports..... Percent in compliance.....	366 (99.2)	2,317 (99.8)	220 (100.0)	289 (99.6)	273 (99.3)	1,573 (99.2)	131 (98.2)	805 (98.4)	297 (99.0)	831 (99.3)	7,212 (99.3)

^a Data available from "old" radiographic form PHS-4405-3 only.

Table 7. Fluoroscopic workload by type of facility
(Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Type of facility	Fluoroscopic workload (Averages are per machine per week)									
	Examination type						Spot films		Total number of milliamperes- minutes ^a	
	Chest ^a		Gastrointestinal		Other					
	Number of reports	Average	Number of reports	Average	Number of reports	Average	Number of reports	Average	Number of reports	Average
Radiologists.....	142	11.3	636	10.6	91	7.1	353	73.1	319	145
Hospitals.....	433	10.6	2,315	13.3	345	14.7	1,234	84.8	889	189
Multiple specialty clinics.....	85	8.3	121	15.0	18	14.4	95	58.5	50	347
Internists.....	304	6.5	225	6.9	117	7.1	77	24.8	194	46
General practitioners.....	316	5.1	506	4.9	239	4.3	225	18.1	330	39
All other facilities.....	144	6.2	266	8.4	79	3.5	123	64.9	124	83
All facilities.....	1,404	8.0	3,984	11.2	869	7.1	2,107	71.1	1,506	119

^a Data available from "old" fluoroscopic form, PHS-4495-2 only.
^b Data available from "new" fluoroscopic form, PHS-4495-3 only.

Table 8. Distribution of fluoroscopic machines by recommendations as specified in NBS Handbook 76 (1)
and by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Recommendations	Type of facility						
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners	All others	All facilities
Leaded drapes around screen:							
Number of reports.....	507	1,950	163	307	934	396	4,477
Percent in compliance.....	(48.2)	(40.9)	(21.5)	(11.2)	(12.9)	(19.9)	(29.5)
Bucky slot covers:							
Number of reports.....	514	1,938	155	396	839	368	4,230
Percent in compliance.....	(55.4)	(65.1)	(31.6)	(16.7)	(20.0)	(29.1)	(43.9)
Manually reset cumulative timer:							
Number of reports.....	516	2,000	164	631	1,030	447	4,788
Percent in compliance.....	(61.0)	(62.8)	(39.6)	(28.5)	(24.4)	(31.3)	(45.1)
Useful beam limited to screen:							
Number of reports.....	504	1,942	160	612	982	430	4,630
Percent in compliance.....	(70.4)	(75.4)	(59.4)	(46.4)	(47.8)	(57.4)	(64.2)
Filtration not less than 2.5 mm. of aluminum equivalent:							
Number of reports.....	355	1,293	124	449	829	335	3,404
Percent in compliance.....	(94.6)	(90.9)	(83.1)	(66.6)	(54.2)	(60.6)	(75.7)
Röntgen output is 10 R/min or less:							
Number of reports.....	503	1,903	160	596	943	393	4,318
Percent in compliance.....	(94.2)	(84.8)	(88.1)	(74.7)	(79.2)	(82.4)	(87.1)
Leaded apron:							
Number of reports.....	521	2,024	169	636	1,076	461	4,887
Percent in compliance.....	(99.2)	(98.7)	(97.0)	(93.6)	(86.3)	(90.0)	(95.2)
Leaded gloves:							
Number of reports.....	521	2,026	168	635	1,064	461	4,875
Percent in compliance.....	(98.6)	(98.4)	(98.2)	(93.8)	(90.2)	(93.0)	(96.5)
Leaded screen is satisfactory: ^a							
Number of reports.....	232	891	58	245	414	141	1,981
Percent in compliance.....	(97.8)	(98.6)	(96.6)	(93.9)	(85.9)	(96.4)	(96.8)
Within target-to-panel distance limits:							
Number of reports.....	494	1,839	148	606	972	421	4,490
Percent in compliance.....	(100.0)	(99.5)	(98.6)	(94.1)	(91.6)	(95.5)	(98.9)
Screen is ganged to x-ray tube:							
Number of reports.....	514	1,993	166	625	1,022	444	4,764
Percent in compliance.....	(99.8)	(99.6)	(95.8)	(97.4)	(96.0)	(94.4)	(97.9)
Deadman exposure switch:							
Number of reports.....	515	1,989	162	625	1,018	441	4,750
Percent in compliance.....	(99.6)	(99.0)	(99.4)	(98.6)	(98.9)	(98.2)	(98.9)

^a Data available from "new" fluoroscopic form, PHS-4495-3 only.

Distribution of radiographic machines by recommendations as specified in NBS Handbook 76 and by type of facility

Table 6 reflects the extent to which the surveyed x-ray equipment complied with those recommendations of the NBS Handbook 76 (1) considered to be most important from the standpoint of radiation safety. The data indicate that the use of gonadal shields as a means of reducing genetic dose has not obtained widespread usage, that insufficient filtration is frequently encountered in many machines and that some operators may be unnecessarily exposed because of location of the exposure switch.

Fluoroscopic workload by type of facility

Table 7 shows the workload per machine, per week, by type of facility. As in other related tables, the greatest workloads are found in hospitals, radiologists' offices, and multiple specialty clinics.

Distribution of fluoroscopic machines by recommendations as specified in NBS Handbook 76 and by type of facility

Table 8 indicates several fluoroscopic problem areas: inadequate filtration, lack of manually reset cumulative timers, useful beam not limited to screen, no Bucky slot covers or leaded drapes around screen, and in some facilities excessive roentgen output at the panel or table top. It is interesting to note that general practitioners and internists tend to have equipment that is deficient in these items more frequently than other types of facilities. It is felt that this may be due partly to the use of older fluoroscopic machines.

Distribution of fluoroscopic machines by items of special interest and by type of facility

In table 9, two items of special interest are: the distribution of image intensifying devices, and the amount of time used for dark adaptation by the different types of facilities. There appears to be some correlation between image intensifying devices and dark adaptation in those facilities where the majority of these devices are located, except for the general practitioner category for which 17.6 percent reported no dark adaptation.

The majority of the image intensifying devices whose use results in lower patient exposure are found in high workload facilities.

Distribution of radiographic procedure reports by body area of examination and by type of facility

Table 10 shows the distribution of the four major body areas of examination by type of facility. Radiographic procedures were performed most frequently on the chest except in those facilities where one would not expect the chest examination to be one of the two most usual radiographic procedures (e.g., podiatrist).

Distribution of radiographic procedure reports by body area of examination and by type of machine

Table 11 shows the distribution of the body areas of examination by type of machine used. For the fixed radiographic and photofluorographic machines, the largest percentage of reports are of chest examination procedures, but for mobile radiographic machines, the largest percentage of reports are of the "all other" category of examination procedures. The larger "all other" examination percentage for this mobile machine category may be explained by the fact that the majority of these machines were located in hospitals where their use is varied.

Percent distribution of radiographic procedure reports by kilovolt peak, milliamperes-second, film size, source to film distance, beam shape, and by body area of examination

Tables 12 to 16 show the wide variation in technique parameters that were reported used for the four major body areas of examinations.

Percent distribution of radiographic procedure reports by collimation as reported by surveyor and by body area of examination

Table 17 presents a summary of the collimation status of radiographic procedures relatable to the size of the film receptor as subjected to interpretation by the surveyor of his respective State program regulations and/or recommendations at the time of survey. From this table, it is evident that improper collimation of the useful beam is a problem of considerable magnitude for all body areas of examination.

Table 9. Distribution of fluoroscopic machines by items of special interest and by type of facility
(Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Items of special interest	Type of facility						
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners	All others	All facilities
Image intensifying device:							
Number of reports.....	512	2,063	158	696	1,071	470	4,350
Percent having device.....	(20.1)	(25.6)	(10.6)	(1.7)	(2.0)	(7.9)	(14.5)
Dark adaptation (minutes):*							
Number of reports.....	876	140	451	475	1,795	275	4,012
Percent reporting none.....	(11.4)	(10.0)	(4.2)	(7.7)	(17.6)	(13.1)	(13.0)
10 or less.....	(40.8)	(20.0)	(47.7)	(19.4)	(14.3)	(30.9)	(27.1)
11-15.....	(21.3)	(25.4)	(31.5)	(27.4)	(23.6)	(22.3)	(28.4)
Greater than 15.....	(26.5)	(43.6)	(16.6)	(45.5)	(42.6)	(12.7)	(34.5)
Lighttight room:							
Number of reports.....	490	1,730	133	583	909	343	4,214
Percent in compliance.....	(90.0)	(83.9)	(81.5)	(83.3)	(78.3)	(20.6)	(82.4)

* No set time is required for dark adaptation as this varies with the equipment used and the ability and age of user. However, at least 10 minutes is recommended when no image intensification is used.

Table 10. Distribution of radiographic procedure reports by body area of examination and by type of facility
(Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Type of facility	Body area of examination													
	Chest		Abdomen		Extremity		Spine		All others		Unknown*		All body areas	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Radiologists.....	571	38.6	347	23.4	135	9.1	94	6.4	230	15.5	103	7.0	1,480	100.0
Hospitals.....	3,380	31.2	1,067	15.8	1,027	9.7	410	3.9	2,363	22.4	1,790	17.0	10,546	100.0
Multiple specialty clinics.....	303	38.3	97	12.2	102	12.9	54	6.8	132	16.7	104	13.1	792	100.0
Internists.....	579	48.2	83	6.9	102	8.5	32	3.7	173	14.4	231	19.3	1,200	100.0
General practitioners:														
Clinics.....	368	45.4	110	12.0	196	23.0	20	2.3	101	11.8	39	4.6	834	100.0
Private practice.....	2,328	41.4	557	9.9	1,170	20.8	168	3.0	792	14.1	605	10.8	5,630	100.0
Osteopaths.....	179	32.5	28	5.9	132	24.0	47	8.0	100	18.2	54	9.8	550	100.0
Podiatrists.....	4	.2	5	.3	719	45.4	120	7.6	275	17.4	481	29.1	1,884	100.0
Chiropractors.....	106	3.1	29	.9	60	2.1	1,787	53.1	782	23.2	593	17.6	3,366	100.0
All others.....	731	23.5	251	8.0	486	15.0	275	8.8	912	29.3	470	15.4	3,114	100.0
Total number of reports.....	8,478	26.1	3,184	10.0	4,118	14.2	3,007	10.3	5,860	20.2	4,450	15.3	29,106	100.0

* Includes coding error, not performed, not reported, and undetermined.

Table 11. Distribution of radiographic procedure reports by body area of examination and by type of machine
(Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Type of radiographic machine	Body area of examination													
	Chest		Abdomen		Extremity		Spine		All others		Unknown*		All body areas	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Fixed.....	6,809	30.2	2,900	12.9	3,259	14.5	2,649	11.7	4,001	17.7	2,938	13.0	22,556	100.0
Fluoroscopic.....	207	43.9	27	5.7	25	5.3	15	3.2	102	21.6	96	20.3	472	100.0
Mobile.....	1,303	23.7	224	4.2	762	14.3	301	5.7	1,475	27.8	1,292	24.3	5,316	100.0
Other and unknowns.....	200	20.2	33	4.3	72	9.5	42	5.5	283	37.0	133	17.8	762	100.0
Total number of reports.....	8,478	29.1	3,184	10.0	4,118	14.2	3,007	10.3	5,860	20.2	4,450	15.3	29,106	100.0

* Unknown includes coding error, not performed, not reported, and undetermined.

Table 12. Percent distribution of radiographic procedure reports by kV peak and by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Kilovolt peak	Body area of examination (percent)						
	Chest (N=3,478)	Abdomen (N=3,184)	Extremity (N=4,118)	Spine (N=3,007)	All other (N=5,880)	Unknown* (N=4,459)	All body areas (N=29,106)
Less than 60.....	5.3	3.3	49.3	6.6	12.0	3.5	12.7
60-69.....	29.0	20.6	37.2	25.9	11.8	2.9	20.2
70-79.....	28.9	40.3	9.5	37.9	10.7	2.9	24.9
80-89.....	15.2	25.0	3.1	20.5	8.5	2.4	11.6
90-99.....	3.1	5.6	1.1	3.5	1.7	.4	2.4
100 and over.....	2.7	6.3	3.5	2.6	34.8	1.3	9.4
Unknown*.....	5.3	.5	6.3	2.8	14.5	85.6	18.8

* Includes coding error, not performed, not recorded, and undetermined.

Table 13. Percent distribution of radiographic procedure reports by milliamperes-seconds and by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Milliamperes-seconds	Body area of examination (percent)						
	Chest (N=3,478)	Abdomen (N=3,184)	Extremity (N=4,118)	Spine (N=3,007)	All other (N=5,880)	Unknown* (N=4,459)	All body areas (N=29,106)
Less than 10.....	34.8	37.1	35.0	9.9	11.3	2.2	19.9
10-19.....	37.0	1.0	31.8	5.2	5.0	2.2	21.5
20-29.....	7.8	3.0	9.3	3.3	4.6	1.1	5.5
30-39.....	1.9	3.6	6.1	4.6	4.6	.9	3.4
40-49.....	.8	4.0	1.4	4.1	3.4	.8	2.4
50-59.....	1.3	27.5	13.9	23.8	14.6	1.3	10.9
60-69.....	.7	11.8	4.4	19.4	6.3	.8	5.5
70-79.....	1.0	9.3	3.1	23.3	4.7	4.5	5.8
80-89.....	.7	.3	.1	.4	.4	.4	.4
90-99.....	4.1	2.0	2.9	3.6	44.9	86.1	24.4
Unknown*.....							

* Includes coding error, not performed, not recorded, and undetermined.

* Data available from "new" radiographic form PHB-4400-3 only.

* Less than 0.1 percent.

Table 14. Percent distribution of radiographic procedure reports by film size and by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Film size (inches)	Body area of examination (percent)						
	Chest (N=3,478)	Abdomen (N=3,184)	Extremity (N=4,118)	Spine (N=3,007)	All other (N=5,880)	Unknown* (N=4,459)	All body areas (N=29,106)
8 by 10.....	0.5	1.0	34.8	18.7	9.5	4.5	9.7
10 by 12.....	1.4	27.4	49.0	18.2	22.5	3.1	17.2
14 by 17.....	94.0	66.7	12.4	51.0	30.0	5.7	46.8
Other*.....	2.1	2.0	2.5	10.6	3.1	.7	3.0
Unknown*.....	2.0	2.9	1.3	1.5	44.9	86.0	23.5

* Includes coding error, not performed, not recorded, and undetermined.

* Includes 5- by 7-, 14- by 36-, and 8- by 36-inch films, and photofluorographic films.

Table 15. Percent distribution of radiographic procedure reports by source to film distance and by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Source to film distance (inches)	Body area of examination (percent)						
	Chest (N=3,478)	Abdomen (N=3,184)	Extremity (N=4,118)	Spine (N=3,007)	All other (N=5,880)	Unknown* (N=4,459)	All body areas (N=29,106)
Less than 30.....	2.7	43.5	41.3	27.9	10.7	3.8	18.8
30-39.....	3.1	7.0	22.4	25.5	10.3	4.5	10.0
40-49.....	4.3	39.4	20.1	19.4	13.1	3.5	12.2
50-59.....	9.2	15.4	13.2	34.6	10.6	1.5	11.4
60 or more.....	80.0	2.3	2.3	4.0	2.4	1.2	25.0
Unknown*.....	.7	3.4	.8	.8	43.9	85.5	22.6

* Includes coding error, not performed, not reported, and undetermined.

Table 16. Percent distribution of radiographic procedure reports by beam shape and by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Beam shape	Body area of examination (percent)						All body areas (N=29,168)
	Chest (N=8,478)	Abdomen (N=3,184)	Extremity (N=4,118)	Spine (N=3,007)	All other (N=5,980)	Unknown* (N=4,480)	
Circular.....	61.5	41.1	71.2	60.7	30.9	10.8	46.6
Square.....	0.1	30.1	8.8	13.6	8.6	.7	9.8
Rectangular.....	27.1	19.5	13.8	18.1	10.8	2.5	16.0
Unknown*.....	5.3	13.3	6.2	7.6	49.7	68.0	27.8

* Includes coding error, not performed, not recorded, and undetermined.

Table 17. Percent distribution of radiographic procedure reports by collimation as reported by surveyor and by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Collimation	Body area of examination (percent)						All body areas (N=29,168)
	Chest (N=8,478)	Abdomen (N=3,184)	Extremity (N=4,118)	Spine (N=3,007)	All other (N=5,980)	Unknown* (N=4,480)	
Proper collimation ^b ..	57.8	76.8	62.5	69.8	50.7	17.3	54.1
Improper collimation ^c ..	36.3	20.3	34.6	24.1	33.8	7.8	28.0
Unknown*.....	5.8	3.3	2.9	6.1	15.5	75.0	17.9

* Includes coding error, not performed, not recorded, and undetermined.

^b Includes variable collimator and permanent collimation installed by surveyor.

^c Includes "proper cone not available."

Percent distribution of radiographic procedure reports by collimation as determined from beam diameter and film size and by fiscal year period

Table 18 presents collimation data comparing the film size to the diameter or diagonal of the useful beam-dimensions which were recorded separately from the surveyor's judgment of collimation as reported in table 17. As seen in table 18 this method of evaluating collimation is more conservative than the surveyor's judgment and even though progress has been made throughout the years there remains room for substantial improvement.

Beam diameter as reported for a 14-by 17-inch film used with circular collimation by type of facility

Table 19 presents collimation data as reported for a 14- by 17-inch film used with circular-shaped beam by type of facility according to recommendations of the National Council on Radiation Protection and Measurements (NCRP) Report No. 33 (2). NCRP Report No. 33 states that "the size of the x-ray beam projected by fixed aperture cones and collimators should not exceed the di-

mensions of the x-ray film by more than 2 inches for a source-film distance of 72 inches or 1 inch for a source-film distance of 36 inches." Hence, the upper limit of the beam diameter of a circular collimator used with a 14- by 17-inch film at 72 inches is 16 inches. When one applies this criterion to the survey data, it becomes evident that collimation of the useful beam according to present day recommendations is totally inadequate.

Beam diameter as reported for a 14- by 17-inch film used with circular collimation by fiscal year periods

Table 20 presents the collimation data contained in table 19 for three fiscal year periods. Essentially no change is noted during this time period.

Distribution of fluoroscopic procedure reports by body area of examination and by type of facility

Table 21 shows that the radiologists and hospitals are performing the majority of the fluoroscopic examinations. When this information is compared with the data contained in tables 6 and 8, it is evident that better protection is being

Table 18. Percent distribution of radiographic procedure reports by collimation as determined from beam diameter* and film size by fiscal year periods (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Collimation as determined from beam diameter* and film size	Fiscal year periods							
	1963-1964		1965-1966		1967-1968		All periods	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Appropriate for size of film used ^b	817	40.0	5,508	49.8	4,456	67.0	10,775	54.8
Excessive for size of film used ^c	1,228	60.0	5,535	50.2	2,107	32.1	8,871	45.2
Total number of reports	2,045	100.0	11,043	100.0	6,563	100.0	19,646	100.0

* Or diagonal.

^b Beam diameter or diagonal is less than or equal to 11 inches for 5- by 7-inch film; 15 inches for an 8- by 10-inch film; 18 inches for a 10- by 12-inch film; 24 inches for a 14- by 17-inch film.

^c Beam diameter or diagonal exceeds limitations in footnote ^b.

Table 19. Beam diameter as reported for 14- by 17-inch film used with circular collimation by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Type of facility	Beam diameter					
	16 inches or less (d)		Greater than 16 inches		Total number of reports	
	Number	Percent	Number	Percent	Number	Percent
Radiologists	12	2.7	425	97.3	437	100.0
Hospitals	97	3.8	2,431	96.2	2,528	100.0
Multiple specialty clinics	4	1.6	250	98.4	254	100.0
Internists	4	1.0	396	99.0	400	100.0
General practitioners in:						
Clinics	9	3.1	285	96.9	294	100.0
Private practice	48	2.6	1,779	97.4	1,827	100.0
Osteopaths	8	4.7	162	95.3	170	100.0
Chiropractors	88	12.6	610	87.4	698	100.0
All others	75	6.0	1,173	94.0	1,248	100.0
All facilities	345	4.4	7,515	95.6	7,860	100.0

Table 20. Beam diameter as reported for 14- by 17-inch film used with circular collimation by fiscal year periods (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Beam diameter	Fiscal year periods							
	1963-1964		1965-1966		1967-1968		All periods	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
16 inches or less (d)	43	5.0	171	3.7	131	5.5	344	4.4
Greater than 16 inches	805	95.0	4,449	96.3	2,230	94.5	7,504	95.6
Total	847	100.0	4,620	100.0	2,361	100.0	7,848	100.0

provided for the patient and operator in these facilities than in the other types of facilities. Internists and general practitioners as a group present the opposite picture insofar as radiation safety is measured by the factors considered in this report. It would appear that more effort with these particular user categories with regard to equipment and accessory shielding recommendations is required.

Distribution of fluoroscopic procedure reports by body area of examination and by type of machine

Table 22 shows that approximately 13 percent of the fluoroscopic examinations in this sample were performed on vertical fluoroscopic equipment. Such equipment is largely found in the offices of general practitioners and internists.

Table 21. Distribution of fluoroscopic procedure reports by body area of examination and by type of facility
(Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Type of facility	Body area of examination					
	Chest*		Gastrointestinal		Total	
	Number	Percent	Number	Percent	Number	Percent
Radiologists.....	142	10.1	638	16.0	780	14.5
Hospitals.....	433	30.9	2,215	55.6	2,648	49.2
Multiple specialty clinics.....	65	4.6	121	3.2	196	3.6
Internists.....	304	21.6	225	5.6	529	9.8
General practitioners.....	316	22.5	500	12.8	825	15.3
All other facilities.....	144	10.3	266	6.7	410	7.6
Total number of reports.....	1,404	100.0	3,984	100.0	5,388	100.0

* Data available from "old" fluoroscopic form, FH8-4495-2 only.

Table 22. Distribution of fluoroscopic procedure reports by body area of examination and by type of machine
(Medical X-ray Protection Survey Reports, fiscal year 1963-1968)

Type of fluoroscopic machine	Body area of examination					
	Chest*		Gastrointestinal		Total	
	Number	Percent	Number	Percent	Number	Percent
Vertical table.....	453	32.3	240	6.0	693	12.9
Tilting table (includes horizontal).....	918	65.4	3,728	93.6	4,646	86.2
Other.....	33	2.3	16	.4	49	.9
Total number of reports.....	1,404	100.0	3,984	100.0	5,388	100.0

* Data available from "old" fluoroscopic form, FH8-4495-2 only.

Percent distribution of operating factors reported for fluoroscopic examinations by body area of examination

Table 23 shows the wide range of operating factors that were reported for the respective examinations. This can be partially accounted for by the use of image intensification devices, poor dark adaptation, the age of the fluoroscopic screen (since the screens deteriorate with age), source-to-panel distance, and the lighttightness of the room.

Figures 1 through 5 are graphic presentations of the radiographic procedure parameter data shown in tables 12 through 16, omitting the category "Unknown." The characteristics of radiographic technique which are more predominant than for another become more evident, although the wide variation in technique parameters remains the dominant feature.

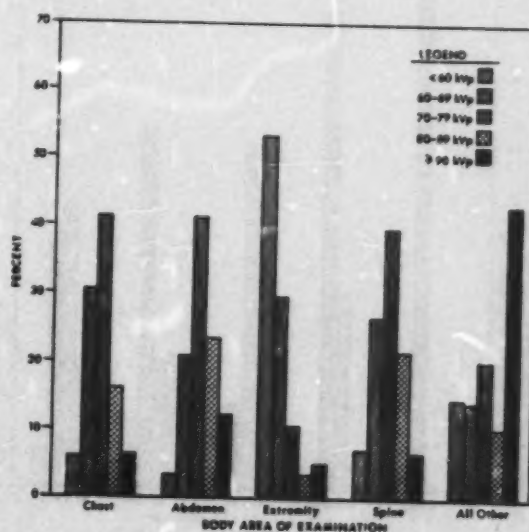


Figure 1. Percent distribution of kilovolt peak reported for radiographic procedures by body area of examination

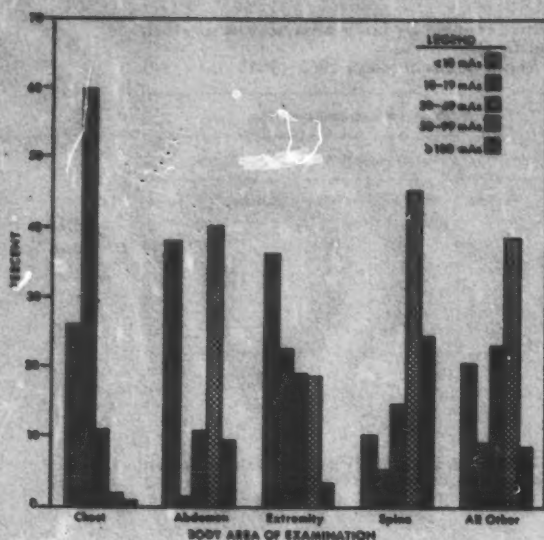


Figure 2. Percent distribution of milliamperage-seconds reported for radiographic procedures by body area of examination

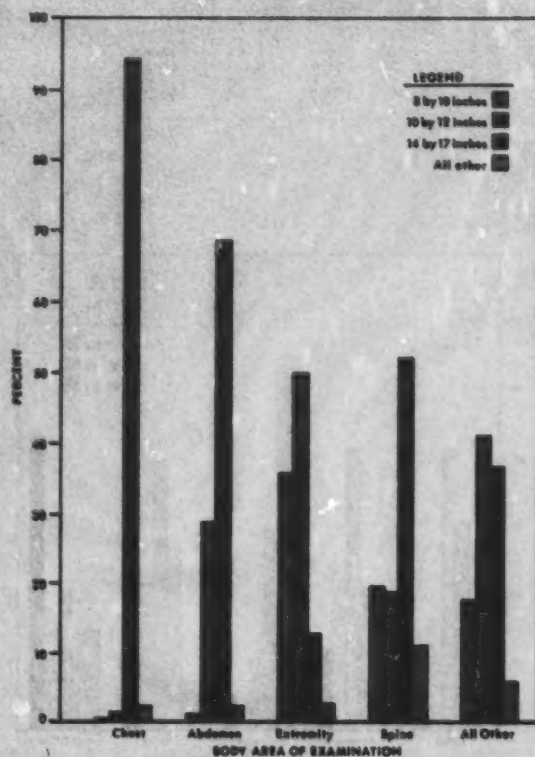


Figure 3. Percent distribution of film sizes reported as used for radiographic procedures by body area of examination

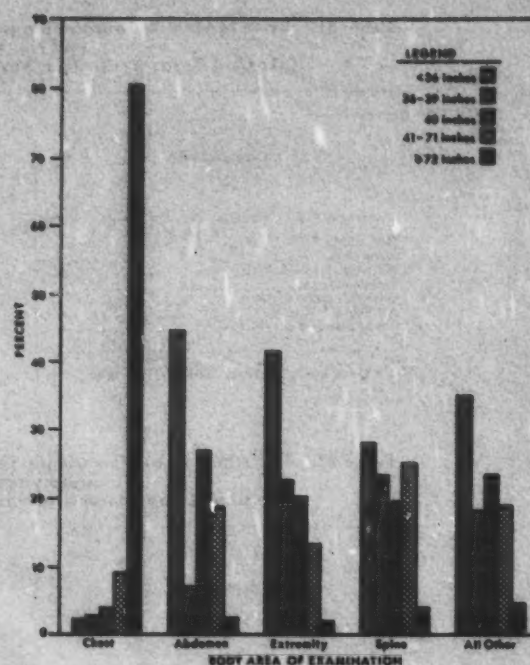


Figure 4. Percent distribution of source to film distance reported for radiographic procedures by body area of examination

Figures 6 and 7 are graphic presentations of the radiographic collimation data contained in tables 17 and 18, omitting the category "Unknown". As seen in figure 6, the need for improvement in collimation is evident when one compares the "improper collimation" bar to the "proper collimation" bar for each of the four major body areas of radiographic examination. It can also be seen in figure 7 that despite improvement in collimation status over the time period of this report, there remains even in the most recent period of fiscal year 1987 and 1988, a large proportion of procedures for which the beam size is excessive for the size of the film used. Figures 8, 9, and 10 are graphic presentations of the fluoroscopic procedure parameter data contained in tables 21, 22, and 23. They indicate the variation in technique parameters within and between chest and gastrointestinal tract examinations more readily than do the tables of numbers.

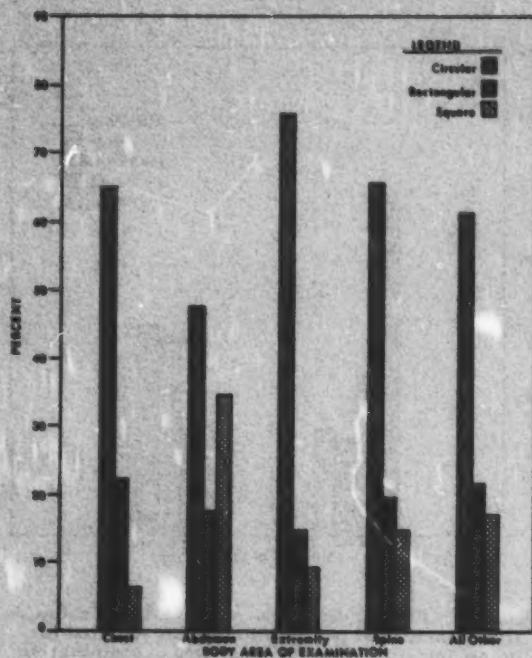


Figure 5. Percent distribution of beam shape reported for radiographic procedures by body area of examination

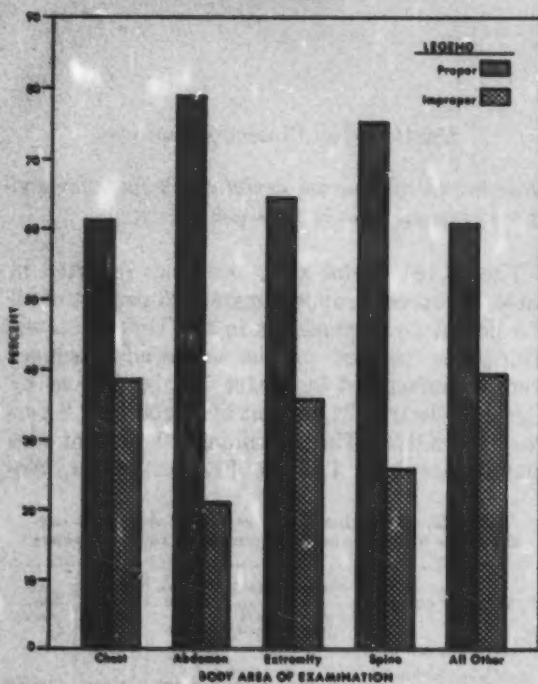


Figure 6. Collimation as reported by surveyor for radiographic procedures by body area of examination

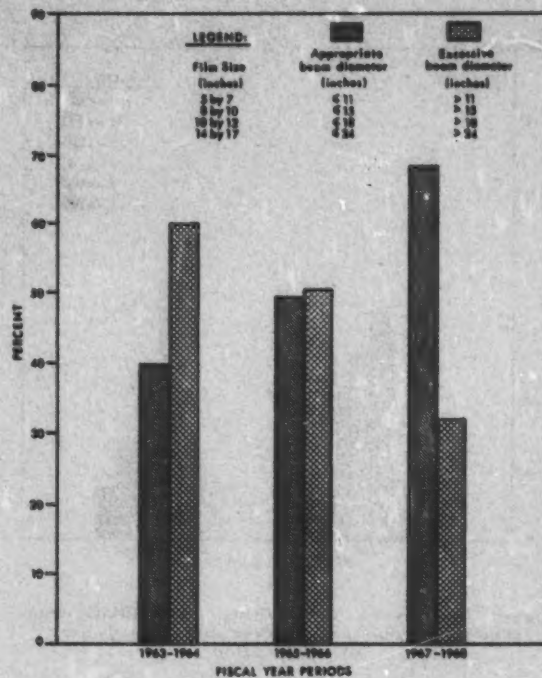


Figure 7. Collimation as determined from beam diameter and film size for radiographic procedures by fiscal year periods

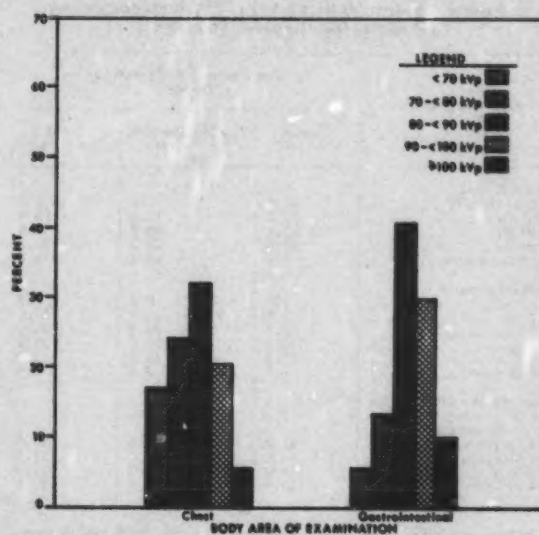


Figure 8. Percent distribution of kilovolt peak reported for fluoroscopic procedures by body area of examination

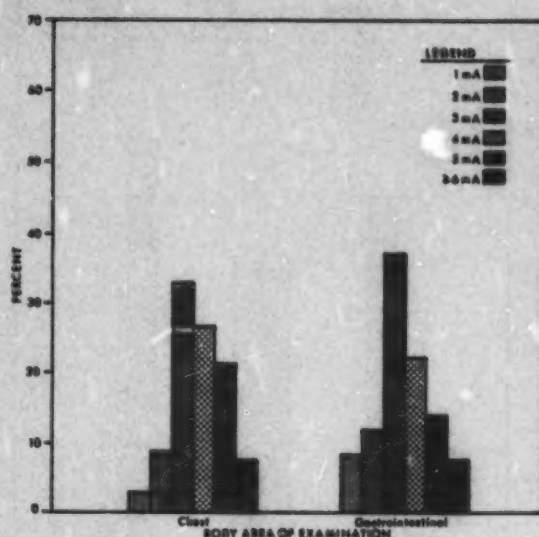


Figure 9. Percent distribution of milliamperage reported for fluoroscopic procedures by body area of examination

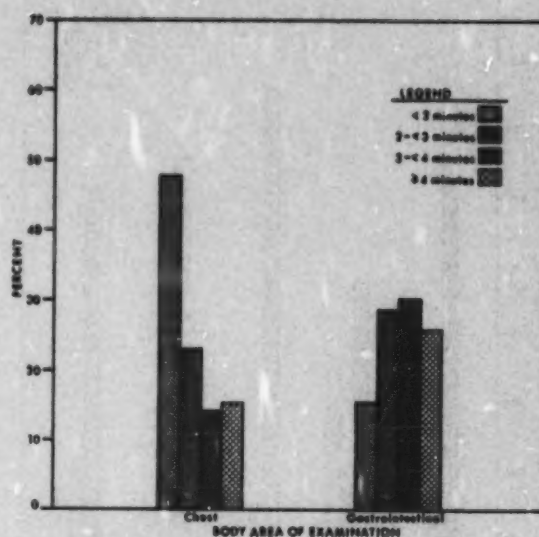


Figure 10. Percent distribution of number of minutes tube is activated per examination as reported for fluoroscopic procedures by body area of examination

Table 23. Percent distribution of operating factors reported for fluoroscopic examinations by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963-1968)

Operating factor	Body area of examination (Percent)		
	Chest* (N=1,404)	Gastrointestinal (N=3,984)	Total (N=5,388)
Kilovolt peak:			
Less than 70.....	17.2	5.8	8.9
70-79.....	24.3	13.5	16.4
80-89.....	32.1	40.7	36.4
90-99.....	30.6	29.8	27.3
100 and over.....	5.8	10.2	9.0
Milliamperage: ^b			
1.....	3.0	8.2	6.7
2.....	8.9	11.7	10.9
3.....	32.8	36.8	35.6
4.....	26.5	22.0	23.2
5.....	21.3	13.8	15.9
6 or more.....	7.5	7.5	7.5
Number of minutes tube is activated per examination: ^c			
Less than 2.....	47.5	15.5	33.8
2 to 3.....	23.0	28.6	27.2
3 to 4.....	14.2	30.1	25.9
4 or more.....	15.3	25.8	23.1

* Data available from "old" fluoroscopic form, PHB-4405-3 only.

^b Average milliamperage for chest examinations is 3.2; for gastrointestinal, 3.6.

^c Average number of minutes tube is activated for chest examination is 2.0; for gastrointestinal, 2.9.

Dental X-ray Protection Surveys

Distribution of reported dental x-ray facilities and of machines surveyed by fiscal years

The 26,104 dental x-ray machines reported in table 24 represent approximately 25 percent of all the dental x-ray machines in the United States. Thirty-one percent of the surveyed machines were manufactured by Ritter Co., 30 percent by General Electric, 21 percent by Weber and 8 percent by XRM. The remaining 10 percent were manufactured by Phillips, Fischer, Meyer, Sie-

Table 24. Distribution of reported dental x-ray facilities and of machines surveyed by fiscal years

Subject of survey	Fiscal years 1961-1962	Fiscal years 1963-1964	Fiscal years 1965-1966	Fiscal years 1967-1968	All fiscal years
Dental x-ray facilities:					
Number surveyed.....	5,058	7,504	4,677	3,825	21,064
Dental x-ray machines:					
Number surveyed.....	5,900	8,988	6,004	5,192	26,104

mens, and others. Ninety percent of the machines surveyed were used by general practitioners; 3 percent by oral surgeons; 3 percent by orthodontists; and 4 percent by other dental specialists.

In this table the fiscal year survey data have been grouped into 2-year intervals in order to put more significant numbers into each category. This format is followed throughout the remaining tables.

The following tables vary in the numbers of facilities and machines reported. This is because the "error," "not stated," "not applicable," and "unknown" categories vary from item to item on the survey reports.

Percent distribution of dental x-ray facilities by reported number of x-ray machines and by fiscal years

Table 25 indicates that the number of x-ray machines per facility is increasing. In the last fiscal-year group surveyed, 27 percent of the facilities had two x-ray machines and 7 percent had three or more machines. This contrasts with the first fiscal year group, which had 15 percent and 3 percent, respectively.

Percent distribution of dental x-ray facilities by reported number of dental personnel and by fiscal years

Ninety percent of dental facilities with full-time dentists are one-man offices (table 26). There appears to be a tendency in the direction of two (or more) man offices. From the 1961-62 period to the 1967-68 period, there was a 2 percent increase in "two or more" full-time dentists per facility. The same trend can be noted in the 3 percent increase in the number of part-time dentists per facility in the total period covered by this report.

Percent distribution of dental x-ray facilities by reported number of ancillary dental personnel and by fiscal years

Twenty-one percent of the facilities were without any full-time dental ancillaries (table 27). This percentage remained almost constant for the entire report period. However, as the category "one full-time ancillary" decreased from 56 percent to 50 percent, the categories "two" and "three-or-more ancillaries" increased. There is

Table 25. Percent distribution of dental x-ray facilities by reported number of x-ray machines and by fiscal years

Reported number of x-ray machines per facility	Percent				
	Fiscal years 1961-1962 (N=5,056)	Fiscal years 1963-1964 (N=7,504)	Fiscal years 1965-1966 (N=4,577)	Fiscal years 1967-1968 (N=3,325)	All fiscal years (N=21,064)
One.....	82	82	74	66	77
Two.....	15	15	21	27	19
Three or more.....	3	3	5	7	4

Table 26. Percent distribution of dental x-ray facilities by reported number of dental personnel and by fiscal years

Reported number of personnel	Percent				
	Fiscal years 1961-1962 (N=8,026)	Fiscal years 1963-1964 (N=7,457)	Fiscal years 1965-1966 (N=4,648)	Fiscal years 1967-1968 (N=3,805)	All fiscal years (N=20,936)
Dentists—full-time:					
None.....	2	3	2	3	2
One.....	91	90	89	88	90
Two or more.....	7	8	9	9	8
Average number of full-time dentists per facility.....	1.08	1.08	1.10	1.09	1.09
Dentists—part-time:					
None.....	06	03	05	03	05
One or more.....	4	5	5	7	5
Average number of part-time dentists per facility.....	0.06	0.07	0.08	0.10	0.08

Table 27. Percent distribution of dental x-ray facilities by reported number of ancillary dental personnel and by fiscal years

Reported number of personnel	Percent				
	Fiscal years 1961-1962	Fiscal years 1963-1964	Fiscal years 1965-1966	Fiscal years 1967-1968	All fiscal years
Ancillaries—full-time:	(N=5,005)	(N=7,412)	(N=4,040)	(N=3,904)	(N=20,361)
None	31	22	31	21	21
One	56	54	50	50	53
Two	17	16	20	19	18
Three or more	6	8	9	10	8
Average number of full-time ancillaries per facility	1.14	1.15	1.23	1.24	1.18
Ancillaries—part-time:	(N=4,948)	(N=7,383)	(N=4,638)	(N=3,900)	(N=20,769)
None	85	83	77	79	81
One	14	14	18	16	15
Two or more	1	3	5	5	4
Average number of part-time ancillaries per facility	0.18	0.21	0.30	0.20	0.24

also a slight increase in the use of part-time ancillaries.

Percent distribution of occupationally exposed personnel in dental facilities

Table 28 points out that 48 percent of full-time dental office personnel are dentists. In the part-time category, only 24 percent are dentists. There is an average of 2.6 occupationally exposed persons per facility of which more are dental ancillaries than dentists. Eighteen percent of the 21,064 dental facilities surveyed reported that they use or had used some form of personnel monitoring. Of these, 51 percent used standard film badges, 44 percent used dental films, 4 percent used pocket dosimeters, and 1 percent used pocket chambers or other devices. However, only 3 percent of the total dental facilities reported using any kind of personnel monitor at the time of the survey.

Table 28. Percent distribution of occupationally exposed personnel in dental facilities

Occupation	Employment status of personnel (percent)		
	Full-time (N=47,380)	Part-time (N=6,476)	All personnel (N=53,857)
Dentists	48	24	45
Ancillaries	52	76	55

Percent distribution of dental x-ray machines by beam diameter and by fiscal years

The data in table 29 indicate that proper collimation of the machines surveyed has largely been accomplished. Even before modification of the machines only 7 percent of the machines surveyed in the fiscal years 1967 and 1968 had a beam diameter greater than the 3 inches recommended as an upper limit in NBS Handbook 76.

Table 29. Percent distribution of dental x-ray machines by beam diameter and by fiscal years

Beam diameter (inches)	Percent				
	Fiscal years 1961-1962	Fiscal years 1963-1964	Fiscal years 1965-1966	Fiscal years 1967-1968	All fiscal years
Before modification:	(N=5,887)	(N=8,837)	(N=5,962)	(N=5,004)	(N=25,710)
2.75 or less	50	55	70	86	64
2.76 to 3.00	14	18	20	7	15
3.01 or greater	36	27	10	7	21
After modification:	(N=5,227)	(N=8,420)	(N=5,886)	(N=4,850)	(N=24,384)
2.75 or less	81	77	77	91	81
2.76 to 3.00	18	21	22	8	18
3.01 or greater	1	2	1	1	1

* On-the-spot modification at the time of the survey.

In fiscal years 1961 and 1962, 36 percent had a beam diameter greater than 3 inches before modification. The continual upgrading of collimation throughout the 8-year period is evident. After modification of the machines in fiscal years 1967 and 1968, only 1 percent of the machines exceeded the 3-inch limit and 91 percent had a beam diameter of 2.75 inches or less as recommended by the American Academy of Dental Radiology (3).

Collimation status of selected dental x-ray machine models before and after modification of beam diameter

Table 30 presents collimation data on some early dental x-ray machines which originally exhibited excessive beam diameters. Before modification,

Table 30. Collimation status of selected dental x-ray machine models before and after modification of beam diameter

Model of dental x-ray machine	Collimation status				Total number of machines surveyed
	Machines having beam diameter greater than 3 inches				
	Before modification		After modification *		
	Number	Percent	Number	Percent	
Ritter A.....	114	50	11	5	220
Ritter B.....	1,845	43	26	1	4,383
Ritter D.....	671	39	11	1	1,742
Weber S.....	64	36	0	0	176
Weber G.....	535	54	3	1	596
Weber GA.....	218	32	6	1	677
Weber Rados					
TD.....	133	24	6	1	562
XRM 2A.....	85	31	7	3	377
XRM 2A.....	145	30	15	4	404
XRM 90.....	99	15	13	2	670
Fischer.....	149	38	12	3	378
Summary.....	4,054	39	118	1	10,484

* On-the-spot modification at the time of the survey.

modification, 39 percent had beam diameters in excess of 3 inches. After modification, only 1 percent had beam diameters in excess of 3 inches demonstrating that even older models of x-ray machines can be modified to meet this recommended standard.

Percent distribution of dental x-ray machines by total filtration in millimeters of aluminum equivalent and by fiscal years

State filtration requirements vary somewhat, but those of NBS Handbook 76 are the most widely accepted. All of the States in this report recommended or required the Handbook 76 figure of at least 1.5 mm. of aluminum equivalent.

In the first fiscal year group of this report, 47 percent of the machines had less than the recommended 1.5 mm of aluminum equivalent before modification (table 31). In fiscal years 1967 and 1968, only 2 percent of the machines did not have at least 1.5 mm aluminum equivalent after modification.

Percent distribution of dental x-ray machines by roentgen output at the cone tip and by fiscal years

Table 32 reflects the results of modifying the filtration of the x-ray machine over the reporting period. With increased filtration, roentgen output is reduced since most of the unnecessary "soft" x-rays are filtered out. In the fiscal year group 1961 and 1962, 21 percent of the machines surveyed had an exposure rate of more than 2.5 R/s before modification, compared to only 6 percent of the machines in fiscal year group 1967 and 1968. At the same time the proportion of machines delivering 1.0 R/s or less increased from 27 percent to 49 percent. After modification, 53

Table 31. Percent distribution of dental x-ray machines by total filtration in millimeters of aluminum equivalent and by fiscal years

Total filtration (mm of Al equivalent)	Percent				
	Fiscal years 1961-1962	Fiscal years 1963-1964	Fiscal years 1965-1966	Fiscal years 1967-1968	All fiscal years
Before modification:	(N = 5,940)	(N = 5,844)	(N = 5,923)	(N = 4,986)	(N = 25,601)
Less than 1.5.....	47	36	17	8	25
1.5 to 2.4.....	43	51	62	62	54
2.5 or greater.....	10	13	21	30	17
After modification:	(N = 5,358)	(N = 3,494)	(N = 5,868)	(N = 4,000)	(N = 24,620)
Less than 1.5.....	3	3	2	2	3
1.5 to 2.4.....	85	73	89	85	75
2.5 or greater.....	12	18	20	35	22

* On-the-spot modification to meet recommendations at the time of the survey.

Table 22. Percent distribution of dental x-ray machines by roentgen output at the cone tip and by fiscal years

Roentgen output at cone tip (R/x)	Percent				
	Fiscal years 1961-1962	Fiscal years 1963-1964	Fiscal years 1965-1966	Fiscal years 1967-1968	All fiscal years
Before modification:	(N = 2,146)	(N = 2,297)	(N = 2,573)	(N = 2,773)	(N = 12,004)
1.00 or less	27	36	46	49	39
1.01 to 2.00	32	51	44	45	49
2.01 or more	21	13	6	6	12
After modification:	(N = 2,574)	(N = 2,390)	(N = 2,941)	(N = 2,716)	(N = 11,221)
1.00 or less	59	65	54	53	58
1.01 to 2.00	38	33	43	42	39
2.01 or more	3	2	3	4	3

* On-the-spot modification to meet recommendations at the time of the survey.

Table 33. Percent distribution of dental x-ray machines by estimated workload in milliamperes-seconds per week and by fiscal years

Estimated workload in mAs per week per machine	Percent				
	Fiscal years 1961-1962 (N = 5,716)	Fiscal years 1963-1964 (N = 5,630)	Fiscal years 1965-1966 (N = 5,942)	Fiscal years 1967-1968 (N = 4,841)	All fiscal years (N = 25,038)
200 or less	41	47	47	58	48
201 to 500	35	24	25	23	24
501 to 800	14	12	12	9	13
801 or more	20	17	16	11	16

Table 34. Percent distribution of dental x-ray machines by cone type and by fiscal years

Cone type	Percent				
	Fiscal years 1961-1962 (N = 5,835)	Fiscal years 1963-1964 (N = 5,773)	Fiscal years 1965-1966 (N = 5,902)	Fiscal years 1967-1968 (N = 5,065)	All fiscal years (N = 25,585)
Poisted	92	93	90	89	91
Open	8	7	11	11	9

Table 35. Percent distribution of dental x-ray machines by type of timer and by fiscal years

Type of timer	Percent				
	Fiscal years 1961-1962 (N = 5,880)	Fiscal years 1963-1964 (N = 5,863)	Fiscal years 1965-1966 (N = 5,980)	Fiscal years 1967-1968 (N = 5,047)	All fiscal years (N = 25,770)
Mechanical	71	65	57	51	62
Electrical or electronic	29	35	43	49	38

Table 26. Percent distribution of dental x-ray machines by distance operable from tube head and by fiscal years

Distance operable from tube head	Percent				
	Fiscal years 1961-1962 (N = 5,978)	Fiscal years 1963-1964 (N = 5,903)	Fiscal years 1965-1966 (N = 5,992)	Fiscal years 1967-1968 (N = 5,042)	All fiscal years (N = 23,815)
Less than 6 feet.....	14	11	6	3	9
6 feet or more.....	86	89	94	97	91

Table 37. Percent distribution of lead aprons by machine and by fiscal years

Lead apron	Percent				
	Fiscal years 1961-1962 (N = 5,861)	Fiscal years 1963-1964 (N = 5,841)	Fiscal years 1965-1966 (N = 5,864)	Fiscal years 1967-1968 (N = 5,026)	All fiscal years (N = 23,632)
Present.....	7	21	52	44	29
None.....	93	79	48	56	71

* Includes category of "present but not used," 213 replies or less than one percent of total.

percent of the machines surveyed in fiscal year 1967-1968 produced 1 R/s or less.

Percent distribution of dental x-ray machines by estimated workloads in milliamperes-seconds per week and by fiscal years

In table 33, a trend to a reduced workload per machine per week as estimated in milliamperes-seconds (mAs) per week is observed. This is undoubtedly due to the increased use of faster film as shown in table 38. Otherwise, one would expect a higher mAs workload per machine since the number of films per week per machine as noted in table 39 increased during the period covered by this report.

Percent distribution of dental x-ray machines by cone type and by fiscal years

Table 34 shows that 91 percent of the total dental x-ray machines surveyed were equipped with pointed cones. The remainder were fitted with open cones which are more desirable because there is no plastic material intercepting the useful beam.

Percent distribution of dental x-ray machines by type of timer and by fiscal years

In fiscal years 1967 and 1968, 49 percent of the machines surveyed had electronic timers.

Only 29 percent of the machines had electronic timers in fiscal years 1961 and 1962. This trend, shown in table 35, reflects the increasing number of new machines being surveyed, almost all of which are equipped with electrical or electronic timers. In addition, many older x-ray machines have had electronic or electrical timers installed to replace the mechanical timers.

Percent distribution of dental x-ray machines by distance operable from tube head and by fiscal years

Table 36 shows that 97 percent of the machines in the latest fiscal year grouping had the operator position at least 6 feet from the tube head when the tube head is in position to radiograph the patient as recommended in NBS Handbook 76. This is an improvement over the 86 percent figure recorded for the first fiscal year grouping.

Percent distribution of lead aprons per machine by fiscal years

Table 37 shows that there is a trend to the increased use of leaded aprons for gonadal shielding in dental offices. Forty-four percent in the 1967-1968 fiscal year group were equipped with leaded aprons compared with only 7 percent so equipped in the fiscal year 1961-1962 grouping.

Table 38. Percent distribution of dental x-ray facilities by reported film speed of bite-wing and of periapical film and by fiscal years

Film speed group ^a	Percent				
	Fiscal years 1961-1962	Fiscal years 1963-1964	Fiscal years 1965-1966	Fiscal years 1967-1968	All fiscal years
Bite-wing:	(N=4,327)	(N=6,804)	(N=4,300)	(N=3,083)	(N=17,914)
A.....	6	3	1	1	3
B.....	50	48	35	29	42
C.....	21	17	18	13	18
D.....	23	32	46	57	37
Periapical:	(N=4,117)	(N=6,463)	(N=3,882)	(N=3,067)	(N=17,149)
A.....	3	3	1	1	3
B.....	40	47	34	30	42
C.....	21	18	19	14	18
D.....	35	32	46	55	37

^a American National Standards Institute speed classifications for intraoral dental radiographic film (4).

Speed group	Speed range (in reciprocal rominans)
A	1.8-3.0
B	3.0-6.0
C	6.0-12.0
D	12.0-24.0

Table 39. Percent distribution of dental x-ray machines by average number of films per week per machine and by fiscal years

Average number of films per week per machine	Percent				
	Fiscal years 1961-1962 (N=5,838)	Fiscal years 1963-1964 (N=8,760)	Fiscal years 1965-1966 (N=5,910)	Fiscal years 1967-1968 (N=4,978)	All fiscal years (N=25,496)
Less than 30.....	19	19	14	17	17
30-39.....	27	27	31	32	28
40-49.....	23	23	34	35	28
50-59.....	14	12	16	15	14
60 or more.....	15	19	25	21	21

Percent distribution of dental x-ray facilities by reported film speed of bitewing and of periapical film and by fiscal years

Table 38 indicates the increased use of fast film (Speed-Group D). Little difference in film speed can be noted between the reported use of periapical and bite-wing film by film speed; that is, those offices using speed-group D bite-wing film also used speed-group D periapical film.

Percent distribution of dental x-ray machines by average number of films per week per machine and by fiscal years

Table 39 indicates an increase in workload from the standpoint of the number of films used per machine per week since fiscal years 1961 and 1962.

Percent distribution of dental facilities by presence and use of thermometer and by fiscal years

Before fiscal year 1965, the presence of a thermometer in the darkroom was reported in 70 percent of the facilities (table 40). By fiscal years 1967-1968, the presence of a thermometer in the darkroom had increased to 78 percent, a slight improvement.

Percent distribution of dental facilities by developer temperature^a and by fiscal years

Ninety-five percent of the dental facilities reported developing dental x-ray films at temperatures of 64° F. through 75° F., (table 41). There

^a Developer temperature—temperature reported by the dentist.

has been little change over the years covered by this report.

There is little agreement among dental x-ray film manufacturers regarding a standard time and temperature for film development. However, the 64° F. to 75° F. interval seems to cover the temperature recommendations of the major dental film manufacturers. Within this temperature range, the time of development should be from 3.5 to 7 minutes.

Percent distribution of dental x-ray facilities by x-ray film development time and by fiscal years

Although table 41 indicated that 95 percent of the facilities are developing film between 64° F. and 75° F., less than 40 percent are using 3.5 minutes or more to develop (table 42). This is significant because the time of development is directly related to the temperature of the developing solution. Referring to the tables on developer temperature and development time, one can note that film underdevelopment appears to be common in dentistry. This underdevelopment is undoubtedly accompanied by film (and patient) overexposure in order to achieve a desirable film density. There is only slight improvement over the

time period covered by this report. Fiscal years 1967 and 1968 show that 41 percent of the facilities developed their films for 3.5 or more minutes, whereas only 31 percent of the facilities did so in fiscal years 1961 and 1962.

Percent distribution of dental facilities by reported time period for change of developer and by fiscal years

In table 43, there is a very slight indication of an increase in the frequency with which developing solutions are changed in dental facilities. This may be accounted for by the greater workload as evidenced by the number of films being used per week per machine, and by the increase in the number of machines per facility over the period of this report.

Percent distribution of dental facilities by light-tightness of darkroom and by fiscal years

For all fiscal years, 24 percent of the darkrooms surveyed were reported as not lighttight (table 44). The criterion of lighttightness depended on subjective determinations made by the various State surveyors. Some improvement can be noted over this report period inasmuch as lighttightness in-

Table 40. Percent distribution of dental facilities by presence and use of thermometer and by fiscal years

Developer-thermometer	Percent				
	Fiscal years 1961-1962 (N = 4,530)	Fiscal years 1963-1964 (N = 7,130)	Fiscal years 1965-1966 (N = 4,411)	Fiscal years 1967-1968 (N = 3,570)	All fiscal years (N = 19,641)
Not present.....	37	29	22	21	28
Present.....	70	70	77	78	73
Thermomatic control.....	3	1	<1	1	1
No darkroom.....	<1	<1	<1	<1	<1
Present, not used.....	<1	<1	<1	<1	<1

Table 41. Percent distribution of dental facilities by developer temperature and by fiscal years

Developer temperature*	Percent				
	Fiscal years 1961-1962 (N = 3,640)	Fiscal years 1963-1964 (N = 6,171)	Fiscal years 1965-1966 (N = 3,719)	Fiscal years 1967-1968 (N = 3,025)	All fiscal years (N = 16,555)
<60°F.....	1	<1	<1	<1	<1
61°F.-63°F.....	<1	<1	<1	<1	<1
64°F.-66°F.....	9	5	4	4	5
67°F.-69°F.....	42	39	41	40	40
70°F.-72°F.....	36	40	44	47	41
73°F.-75°F.....	8	11	7	5	9
>75°F.....	4	3	3	3	3

* Developer temperature-temperature reported by the dentist.

Table 42. Percent distribution of dental x-ray facilities by x-ray film development time and by fiscal years

Development time (minutes)	Percent				
	Fiscal years 1961-1962 (N=4,815)	Fiscal years 1963-1964 (N=7,004)	Fiscal years 1965-1966 (N=4,601)	Fiscal years 1967-1968 (N=3,173)	All fiscal years (N=19,593)
Less than 2.5*	20	20	20	20	20
2.5 to 3.5	23	24	20	21	22
3.5 to 4.5	17	21	20	21	20
4.5 or more	14	16	20	20	18

* Includes 762 or 4 percent which were reported as eight developing which is undesirable because of the impedance of the method and possible film fogging due to exposure to white light.

Table 43. Percent distribution of dental facilities by reported time period for change of developer and by fiscal years

Developer change period	Percent				
	Fiscal years 1961-1962 (N=4,815)	Fiscal years 1963-1964 (N=7,004)	Fiscal years 1965-1966 (N=4,601)	Fiscal years 1967-1968 (N=3,099)	All fiscal years (N=18,528)
<3 weeks	5	4	4	6	4
3 to 4 weeks	66	66	74	70	70
4 to 6 weeks	11	11	10	11	11
6 to 8 weeks	10	9	7	9	9
>8 weeks	6	7	5	4	6

Table 44. Percent distribution of dental facilities by lighttightness of darkroom and by fiscal years

Lighttightness	Percent				
	Fiscal years 1961-1962 (N=4,809)	Fiscal years 1963-1964 (N=7,009)	Fiscal years 1965-1966 (N=4,557)	Fiscal years 1967-1968 (N=3,055)	All fiscal years (N=19,430)
Lighttight	60	74	81	85	76
Not lighttight	31	25	19	15	24

creased from 60 percent in the fiscal year period of 1961-1962, to 85 percent by the fiscal year period, 1967-1968.

Percent distribution of dental x-ray machines meeting recommendations as specified in NBS Handbook 76 (1) and by fiscal years

Table 45 indicates that the three items specifically mentioned in NBS Handbook 76 (i.e., distance limitation at which machine is operable, filtration, and collimation) were never overwhelming problems. It should be noted, however, that

the collimation and filtration data reflect onsite modifications made by the surveyor.

The greatest area for future reduction of unnecessary dental x-ray exposure is in the technique and judgment area. This requires that the dentist be educated and motivated to take only those films necessary for proper diagnosis, to use the fastest film available, to develop the films properly in a suitable darkroom, and to interpret them with the aid of proper equipment. At the same time he should continue to improve his diagnostic acumen through continuing education whether through formal courses and seminars or through his professional readings.

Table 44. Percent distribution of dental x-ray machines meeting recommendations as specified in NBS Handbook 76(1) and by fiscal years

Recommendations	Fiscal years 1981-1982	Fiscal years 1983-1984	Fiscal years 1985-1986	Fiscal years 1987-1988	All fiscal years
Machines operable 6 feet or more from table top: Number of machines surveyed.....	5,878	5,932	5,980	5,043	35,815
Percent in compliance.....	88	88	94	97	91
Filtration 1.5 mm of Al equivalent or more after modification: ^a Number of machines surveyed.....	5,388	5,494	5,988	4,909	34,629
Percent in compliance.....	97	97	98	98	97
Beam diameter 8 inches or less after modification: ^a Number of machines surveyed.....	5,227	5,402	5,988	4,939	34,994
Percent in compliance.....	99	98	99	99	99

^a On-the-spot modification to meet the recommendations at the time of the survey.

Conclusions and recommendations

The areas in which major efforts should be made are as follows:

Equipment: The high percentage of medical facilities have improper collimation, especially in view of the more recent recommendations appearing in NCRP Report No. 33, and inadequate filtration indicates that a major effort in these areas is still needed to correct equipment deficiencies. At the same time, the large proportion of facilities in which accessory patient or operator shielding was lacking or inadequate, together with the infrequent use of any personnel monitoring system, identifies additional areas that require attention by user groups and by radiation control programs. This is necessary in order to achieve further reduction of unnecessary radiation to the general population and occupationally exposed medical groups.

Although dental x-ray equipment does not appear to present as significant a population exposure problem as does medical equipment, the universal use of a shielded open-end aiming device, together with the use of Speed Group D film, would further reduce the radiation exposure to the patient and the operator. Related areas needing attention are primarily darkrooms and darkroom procedures which according to the information available in this report vary greatly in quality and preciseness.

Standardization of survey techniques and data collection: The high percentage of "unknowns" in the data reported emphasize the need for the

standardization of surveying techniques and for uniformity and comparability of data collected in State radiological health programs. Survey forms should also be revised using recent NCRP recommendations as a guide, and all data inquiries should be eliminated when they are of doubtful value in defining or assessing radiological health problems and progress.

Insofar as radiation exposure reduction can be affected by items peripheral to the x-ray equipment itself, such as film speed, darkroom procedures, and the like, inquiries should be added to the survey forms to provide State programs a practical basis for action in these areas.

Technique and judgment: A continuing effort aimed at improving the technique of the operator of the machine and the professional judgment of the practitioner requesting the examination is essential if the efforts toward dose reduction are to be successful. This could be accomplished in part if the use of gonadal shielding were as universal as is the presence of deadman-type switches on x-ray equipment. The use of fluoroscopy in cases where a radiograph would serve a more useful purpose, and inadequate beam collimation in facilities where adequate collimating devices are available, reinforce the conclusion that a continuing effort aimed at improving the technique of the machine operator and the professional judgment of the practitioner are required.

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Appendix

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE PUBLIC HEALTH SERVICE		X-RAY PROTECTION SURVEY REPORT FACILITY		SURVEY DURESS NO. 95-008 APPROVAL REQUIRED 9-03-66	
1. NAME OF FACILITY			2. TELEPHONE		
3. LOCATION (STREET OR ROUTE)			4. STATE, COUNTY, CITY		
5. OWNER OF FACILITY (IF DIFFERENT FROM 1)		6. FACILITY LOCATION		7. NO. ASSIGNED BY AGENCY	
8. PERSON INTERVIEWED		9. 1 2 3 4 5 6 7 8 9 0		10 11 12 13 14	
11. PERSON RESPONSIBLE FOR RADIATION SAFETY (NAME AND TITLE)			12. CARD NO.		13. DATE (mo, yr)
14. PREVIOUS RADIATION SAFETY SURVEY			15. 1 2 3 4 5 6 7 8 9 0		16. 10 11 12 13 14
17. YES ☐ NO ☐			DATE		
18. DESCRIPTION OF FACILITY					
19. TYPE OF FACILITY:					
☐ 1. Private Office ☐ 2. Hospital ☐ 3. Clinic ☐ 4. Radio ☐ 5. Other (SPECIFY)					
20. TYPE OF PRACTICE					
21. PERSONNEL					
OCCUPATIONALLY EXPOSED		A. TOTAL			
B. OPERATOR		C. TOTAL			
D. TYPE: ☐ 1. Film Badge ☐ 2. Dosimeter ☐ 3. Bad ☐ 4. Other		E. TIME: ☐ 1. Monthly ☐ 2. Used While Per Year			
22. WORKLOAD (AVE. PER WEEK)		A. RADIOGRAPHIC EXPOSURES			
B. FLUOROSCOPIC EXAMINATIONS		23. EQUIPMENT (TOTAL NUMBER)			
A. UNITS AT THIS INSTALLATION		B. TYPES			
24. FILM AND SCREEN		A. BRAND AND TYPE OF X-RAY FILM USED			
B. TYPE OF INTENSIFYING SCREEN		25. RADIATION LIGHT TIGHT? ☐ 1. Yes ☐ 2. No			
26. FILM PROCESSING		A. TYPE OF DEVELOPER			
B. HOW OFTEN DEVELOPER CHANGED (WEEKS)		C. HOW OFTEN REPLENISHED (DAYS)			
D. TIME (MINUTES)		E. TEMPERATURE			
F. AUTOMATIC		Indicated _____ °F ☐ Unknown			
27. ARE RADIOACTIVE MATERIALS EVER PRESENT		A. YES ☐ 1. Yes ☐ 2. No			
B. OTHER MATERIALS		1. Yes ☐ 2. No			

Figure 11. "Old" facility form—Medical X-ray Protection Survey Reports

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE PUBLIC HEALTH SERVICE		X-RAY PROTECTION SURVEY REPORT RADIOGRAPHIC		BUDGET SYSTEM NO. 68-000 APPROVAL EXPENSE 68-00				
1. NAME OF FACILITY			2. TELEPHONE					
3. LOCATION (STREET OR ROAD)			4. STATE, COUNTY, CITY					
5. LOCATION OF UNIT WITHIN FACILITY (BLDG. AND ROOM NUMBER)			6. FACILITY LOCATION		7. NO. REMOVED BY AGENCY			
			1 2 3 4 5 6 7 8 9		10 11 12 13 14			
8. SURVEYOR OF THIS UNIT			9. CARD I.D.		10. DATE (Mo, Yr)			
A. _____ B. _____			1 2 3 4 5 6 7 8 9		10 11 12 13 14			
EQUIPMENT IDENTIFICATION	11. A. NUMBER ASSIGNED UNIT _____							
	B. CONTROL PANEL MANUFACTURER AND MODEL _____							
	C. TUBE MANUFACTURER AND MODEL _____							
	D. COBBERATION ☐ 1. Yes ☐ 2. No							
	E. ☐ 3. UNDETERMINED ☐ 4. PHOTOFLUOROGRAPHIC ☐ 5. MOBILE							
F. ☐ 6. FIXED RADIOGRAPHIC (SPECS) SPECIAL TYPE _____ ☐ 7. OTHER								
G. NUMBER OF TUBES _____								
H. OTHER IDENTIFICATION (SPECS) _____								
12. FILTRATION (TOTAL MM. AL. EQUIV.) Before _____ After _____			13. ESTIMATED NUMBER OF EXPOSURES PER WEEK					
14. TUBE RATINGS (MAX) K.V.P. _____ M.A. _____			15. TUBE RATINGS (MAX) K.V.P. _____ M.A. _____					
COLLIMATION AND OPERATING SETTINGS FOR VARIOUS TECHNIQUES	16. COLLIMATION AND OPERATING SETTINGS FOR VARIOUS TECHNIQUES							
	Technique	K.V.P.	M.A.S	Film Size	Dist.	Beam Type	Size	Collimation
	1. CHEST	44 45 46 47 48 49	50 51 52	53 54 55	56 57 58	59 60 61	62 63 64	65 66 67
	2. ABDOMEN	57 58 59 60 61 62	63 64 65	66 67 68	69 70 71	72 73 74	75 76 77	78 79 80
	3. EXTREMITY (SPECS)	81 82 83 84 85 86	87 88 89	90 91 92	93 94 95	96 97 98	99 100 101	102 103 104
4. OTHER (SPECS)	105 106 107 108 109 110	111 112 113	114 115 116	117 118 119	120 121 122	123 124 125	126 127 128	
BEAM	17. A. CENTERING DEVICE ☐ 1. Yes ☐ 2. No ☐ 3. R/A							
	B. ALIGNMENT ☐ 4. Unknown ☐ 5. Satisfactory ☐ 6. Unsatisfactory							
TIMER	18. A. TYPE: ☐ 1. Mechanical ☐ 2. Electronic or Electronic ☐ 3. Other							
	B. TERMINATE EXPOSURE ☐ 4. Unknown ☐ 1. Yes ☐ 2. No							
	C. DEADMAN SWITCH ☐ 5. Unknown ☐ 1. Yes ☐ 2. No							
	D. ADEQUATE LOCATION OR CORD LENGTH ☐ 6. Unknown ☐ 1. Yes ☐ 2. No							
PROTECTIVE DEVICES	19. A. GONADAL SHIELD FOR PATIENT ☐ 7. Unknown ☐ 1. Yes ☐ 2. No							
	B. ADEQUATE OPERATOR PROTECTION ☐ 8. Unknown ☐ 1. Yes ☐ 2. No							
	C. PRIMARY AND SECONDARY BARRIERS ADEQUATE ☐ 9. Unknown ☐ 1. Yes ☐ 2. No							
	D. DIAGNOSTIC TYPE TUBE HOUSING ☐ 10. Unknown ☐ 1. Yes ☐ 2. No							
SCATTER RADIATION MEASUREMENTS (REAL READINGS) TAKEN AT K.V.P. _____ M.A. _____	Position		Dose Rate		Position	Dose Rate		
	A. OPERATOR		B. _____		C. _____			
D. _____		E. _____		F. _____				

Figure 12. "Old" radiographic form—Medical X-ray Protection Survey Reports

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE PUBLIC HEALTH SERVICE		X-RAY PROTECTION SURVEY REPORT FLUOROSCOPIC		SUBJECT BUREAU NO. 60-6000 APPROVAL EXP. 6-6-65	
1. NAME OF FACILITY			2. TELEPHONE		
3. LOCATION (STREET OR RAIL)		4. STATE, COUNTY, CITY			
5. LOCATION OF UNIT WITHIN FACILITY (BLDG. AND ROOM NUMBER)		6. FACILITY LOCATION		7. NO. ASSIGNED BY AGENCY	
		1 2 3 4 5 6 7 8 9		10 11 12 13 14	
8. SURVEYOR OF THIS UNIT			9. CARD I. D.		10. DATE (mo, yr)
			1 2 3 4 5 6 7 8 9		10 11 12 13 14
EQUIPMENT IDENTIFICATION	11. 4. NUMBER ASSIGNED UNIT				
	5. CONTROL PANEL MANUFACTURER AND MODEL				
	6. TUBE MANUFACTURER AND MODEL				
	7. COINTEGRATION ☐ 1. Yes ☐ 2. No				
	8. ☐ 1. Vertical ☐ 2. Horizontal ☐ 3. Tilting Table ☐ 4. Other				
	9. IMAGE INTENSIFYING DEVICE USED ☐ 1. Yes ☐ 2. No				
	10. OTHER IDENTIFICATION (SPECIFY)				
ACCESSORY SHIELDING	12. A. GLOVES ☐ 1. Yes ☐ 2. No ☐ 3. N/A				
	B. LEADED APRON ☐ 1. Yes ☐ 2. No ☐ 3. N/A				
	C. BUCKY SLOT COVER ☐ 1. Yes ☐ 2. No ☐ 3. N/A				
	D. LEADED DRAPES AROUND SCREEN ☐ 1. Yes ☐ 2. No ☐ 3. N/A				
	E. OTHER (SPECIFY)				
13. DARK ADAPTATION: (NUMBER OF MINUTES)					
USUAL PROCEDURES	Technique	K.V.P.	M.A.	Min. Tube Activated Per Exam	Expos. Per Week
	A. CHEST	17 18 19	20 21	22 23	24 25
	B. C.J.	26 27 28	29 30	31 32	33 34
	C. OTHER	35 36 37	38 39	40 41	42 43
14. AVERAGE SPOT FILM PROCEDURE: (USUAL) K.V.P. _____ M.A. _____ EXPOSURES PER WEEK					
15. TRANSMISSION THROUGH SCREEN AND LEAD GLASS: (mR/hr)					
SCREEN	17. A. SHUTTERS FUNCTION PROPERLY ☐ 1. Yes ☐ 2. No ☐ 3. Fixed				
	B. PRIMARY BEAM LIMITED TO SCREEN ☐ 1. Yes ☐ 2. No				
	C. FLUOROSCOPIC SCREEN GANGED TO X-RAY TUBE ☐ 1. Yes ☐ 2. No				
TIMER	18. A. DEADMAN - TYPE EXPOSURE SWITCH ☐ 1. Yes ☐ 2. No				
	B. MANUALLY RESET CUMULATIVE TIMER ☐ 1. Yes ☐ 2. No				
	C. CUMULATIVE TIMER TERMINATE EXPOSURE ☐ 1. Yes ☐ 2. No				
19. ROENTGEN OUTPUT AT PANEL SURFACE: (PRIMARY BEAM) _____ R/min.					
20. FILTRATION: (TOTAL MM AL. EQUIV.) Before _____ After _____					
21. DISTANCE FROM TARGET TO PANEL (INCHES)					
22. LIGHT LEAKS IN FLUOROSCOPIC ROOM ☐ 1. Undetermined ☐ 1. Yes ☐ 2. No					
SCATTER RADIATION MEASUREMENTS (MAX. READINGS) TAKEN AT K.V.P. _____ M.A. _____	Position	Dose Rate	Position	Dose Rate	
	A. OPERATOR		C.		
	B.		D.		

PHS 4095-3 (REV. 6-63)

(USE REVERSE SIDE FOR REMARKS)

Figure 13. "Old" fluoroscopic form—Medical X-ray Protection Survey Reports

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE PUBLIC HEALTH SERVICE		X-RAY PROTECTION SURVEY REPORT FACILITY		SUGGEST BUREAU NO. 05-0005 APPROVAL EXPIRES 0-0-00	
1. NAME OF FACILITY		3. TELEPHONE		5. NUMBER ASSIGNED BY AGENCY	
4. LOCATION (Street, Building, Room Number)		7. STATE		CITY	
6. DATE (Mo., Day, Yr.)		8. CARD I.D.		9. CITY	
10. PERSON IN CHARGE OF X-RAY FACILITY		11. PERSON RESPONSIBLE FOR RADIATION SAFETY: NAME		TITLE	
12. PERSON INTERVIEWED:		13. POSITION		DATE:	
14. PREVIOUS RADIATION SAFETY SURVEY: 1. Yes 2. No		15. TYPE OF FACILITY: 1. Private Office 2. Hospital 3. Clinic		16. TYPE OF PRACTICE:	
17. TYPE OF PRACTICE:		18. TYPE OF PRACTICE:		19. TYPE OF PRACTICE:	
PERSONNEL	A. TOTAL NUMBER OCCUPATIONALLY EXPOSED		B. TOTAL NUMBER OF OPERATORS		C. TOTAL NUMBER MONITORED
	D. MONITORING SYSTEM EMPLOYED: 1. _____ 2. _____		E. MONITORING SYSTEM ADEQUATE: 1. Yes 2. No 3. N/A		F. MONITORING RECORDS SATISFACTORY: 1. Yes 2. No 3. N/A
	G. LEVELS/MONTH: _____		H. NUMBER OVER 300 HR/QUARTER		
	A. PATIENTS RADIOGRAPHS (Average per week)		B. PATIENTS FLUOROSCOPED (Average per week)		C. THERAPY TREATMENTS (Average per week)
	A. TOTAL NUMBER OF MACHINES AT THIS FACILITY		B. TOTAL NUMBER OF UNITS (Tubes)		
	A. BRAND AND TYPE OF X-RAY FILM USED		B. TYPE OF INTENSIFYING SCREEN		
	A. DARKROOM LIGHT TIGHT: 1. Yes 2. No		B. TYPE OF DEVELOPER: _____		C. AUTOMATIC PROCESS: 1. Yes 2. No
	D. HOW OFTEN CHANGED (Weeks)		E. HOW OFTEN REPLENISHED (Days)		F. THERMOMETER PRESENT: 1. Yes 2. No 3. Thermomatically controlled
DARKROOM PROCEDURE	G. TEMPERATURE INDICATED: _____°C		H. THERMOMETER PRESENT: 1. Yes 2. No		I. TIME IN DEVELOPER (Minutes)
	A. RADIUM EVER PRESENT: 1. Yes 2. No		B. OTHER ISOTOPES EVER PRESENT: 1. Yes 2. No		
	1. Initial 2. Followup 3. Re-survey		4. Request 5. Completed 6. Other (Specify)		
	A. _____		B. _____		

Figure 14. "New" facility form—Medical X-ray Protection Survey Reports

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE PUBLIC HEALTH SERVICE		X-RAY PROTECTION SURVEY REPORT RADIOGRAPHIC		BUREAU BUREAU NO. 00-0000 APPROVAL, EXPOSURE 0-00-00	
1. NAME OF FACILITY		2. TELEPHONE		3. NUMBER ASSIGNED BY AGENCY	
4. LOCATION (Street, Building, Room Number)		7. STATE		COUNTY CITY	
5. DATE (Mo. Day, Yr.)		6. CLASS		7. TYPE	
8. EQUIPMENT IDENTIFICATION		A. NUMBER ASSIGNED IN CLASS		B. CONTROL PANEL MANUFACTURER	
C. TUBE HEAD MANUFACTURER AND MODEL		D. COMBINATION: 1. Yes 2. No		E. TYPE: 1. Fixed Radiographic (Indicate special type) 2. Fluoroscopic 3. Mobile 4. Other (specify)	
F. NUMBER OF TUBES		G. MAXIMUM KVP (RATED)		H. MAXIMUM MA (RATED)	
9. FILTRATION		A. TOTAL MM. ALUMINUM EQUIVALENT		B. BEFORE C. AFTER	
10. "WORLDWIDE"		A. AVERAGE NUMBER OF PATIENTS PER WEEK (estimate)		B. TOTAL NUMBER OF EXPOSURES PER WEEK (estimate)	
11. USUAL PROCEDURES		EXAMINATION (Specify)		KVP MA TIME HAS EXPOSURES PER WK. FILM SIZE DISTANCE (Inches) BEAM TYPE BEAM SIZE (Inches) COLLIMATION	
12. EXPOSURE SWITCH		A. ADEQUATE LOCATION: 1. Yes 2. No		A B	
13. TIMER		A. ADEQUATE: 1. Yes 2. No		A B	
14. PROTECTIVE DEVICES		A. GONADAL SHIELD FOR PATIENT: 1. Yes 2. No 3. N/A		A B	
B. ADEQUATE OPERATOR PROTECTION: 1. Yes 2. No		C. ADEQUATE PRIMARY AND SECONDARY BARRIERS: 1. Yes 2. No 3. N/A		C D	
D. DIAGNOSTIC-TYPE TUBE HOUSING: 1. Yes 2. No		D		D	
15. STRAY RADIATION MEASUREMENTS		POSITION EXPOSURE RATE MR/HR		POSITION EXPOSURE RATE MR/HR	
A. OPERATOR		D.		E.	
B.		E.		F.	
C.		F.		G.	
MAXIMUM READINGS TAKEN AT KVP _____ MA _____ SECONDS _____)		G.		H.	
16. SURVEYORS		A. _____		B. _____	

PHS-548C-3 (REV 7-68) (Use reverse side for remarks or sketch)

Figure 15. "New" radiographic form—Medical X-ray Protection Survey Reports

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE PUBLIC HEALTH SERVICE		X-RAY PROTECTION SURVEY REPORT FLUOROSCOPIC		SURVEY BUREAU NO. 68- APR 1972, EXPIRES 6-72	
1. NAME OF FACILITY		2. TELEPHONE		3. NUMBER ASSIGNED BY BUREAU	
4. LOCATION (Street, Building, Room Number)		5. STATE		COUNTY	CITY
6. DATE (Mo., Day, Yr.)		7. SARD I.D.		8. SARD	
9. EQUIPMENT IDENTIFICATION		A. NUMBER ASSIGNED MACHINE		B. CONTROL PANEL MANUFACTURER	
		C. TUBE HEAD MANUFACTURER AND MODEL		D. COMBINATION: 1. Yes 2. No	
		E. TYPE: 1. Vertical 2. Horizontal 3. Tilting Table 4. Other		F. MAGE INTENSIFYING DEVICE USED: 1. Yes 2. No	
		G. OTHER IDENTIFICATION (Specify)			
10. ACCESSORY SHIELDING		A. LEADED GLOVES: 1. Yes 2. No		B. LEADED APRON: 1. Yes 2. No	
		C. BUCKY SLOT COVER: 1. Yes 2. No 3. N/A		D. LEADED DRAPES AROUND SCREEN: 1. Yes 2. No 3. N/A	
		E. OTHER (Specify)			
11. DARK ADAPTATION		A. GOGGLES USED: 1. Yes 2. No		B. NUMBER OF MINUTES	
12. USUAL PROCEDURES		EXAMINATION	KVP	MA	MINUTES TUBE ACTIVATED PER EXAMINATION
		A. UPPER S.I.			
		B. LOWER S.I.			
		C. OTHER (Specify)			
		D. TOTAL MA-MH/ WEEK			
13. SPOT FILMS		A. AVERAGE EXPOSURES PER WEEK			
14. SCREEN		A. FLUOROSCOPIC SCREEN GANGED TO X-RAY TUBE: 1. Yes 2. No		A	
		B. LEADED GLASS SATISFACTORY: 1. Yes 2. No 3. N/A		B	
		C. SHUTTERS FUNCTION PROPERLY: 1. Yes 2. No 3. Fixed		C	
		D. USEFUL BEAM LIMITED TO SCREEN: 1. Yes 2. No		D	
		Overlap: Top Right Bottom Left			
15. DISTANCE		A. TARGET TO PANEL (Inches)		A	
16. X-RAY OUTPUT		A. USEFUL BEAM AT PANEL SURFACE: R/MH		A	
17. FILTRATION		A. TOTAL MM. ALUMINUM EQUIVALENT: A. Before B. After		A B	
18. TIMER		A. DEADMAN TYPE EXPOSURE SWITCH: 1. Yes 2. No		A B C	
		B. MANUALLY RESET CUMULATIVE TIMER: 1. Yes 2. No			
		C. CUMULATIVE TIMER TERMINATES EXPOSURE: 1. Yes 2. No			
19. FLUOROSCOPIC ROOM		A. LIGHT TIGHT: 1. Yes 2. No 3. N/A		A	
20. STRAY RADIATION MEASUREMENTS		POSITION	EXPOSURE RATE (MR/HR)	POSITION	EXPOSURE RATE (MR/HR)
		A. OPERATOR		D.	
		B. ABOVE SCREEN		E.	
		C.		F.	
		(MAXIMUM READINGS TAKEN AT KVP MA SEC: 25)			
21. SURVEYORS		A. B.			

PHS-4493-2 (REV. 7-68)

(Use reverse side for remarks or sketch)

Figure 16. "New" fluoroscopic form—Medical X-ray Protection Survey Reports

PHYSICAL RADIATION PROTECTION SURVEY OF DENTAL X-RAY EQUIPMENT INSTALLATION CARD NO. 1		2. STATE, COUNTY, CITY	
1. NAME OF UNIT(S) 2. INSTALLATION ADDRESS 3. PHONE NUMBER 4. CITY 5. COUNTY 6. STATE ZIP CODE 7. NAME OF SURVEYOR		3. DENTIST, CARD IDENTIFICATION	
		4. TOTAL X-RAY UNITS AT INSTALLATION	
		5. X-RAY UNIT IDENTIFICATION NUMBER	
		6. NUMBER OF PERSONS OPERATING THIS UNIT	
		7. NUMBER OF OFFICE PERSONNEL	
		A. FULL TIME DENTISTS	
		B. PART TIME DENTISTS	
		C. OTHER FULL TIME PERSONNEL	
		D. OTHER PART TIME PERSONNEL	
8. TYPE OF PRACTICE			
1. GENERAL 2. ORAL SURGERY 3. ORTHODONTIC 4. PERIODONTIC 5. PERIODONTIC 6. PERIODONTIC 7. MORE THAN ONE TYPE 8. OTHER (SPECIFY)			
9. X-RAY UNIT			
A. MANUFACTURER _____ MODEL _____			
B. TUBE SERIAL NUMBER _____			
C. CONSOLE SERIAL NUMBER _____			
10. PORTER CONE			
1. SHORT POINTED 2. SHORT OPEN 3. LONG POINTED 4. LONG OPEN 5. OTHER (SPECIFY)			
11. FIELD DIAMETER AT END OF PORTER CONE (inches)			
A. BEFORE MODIFICATION _____			
B. AFTER MODIFICATION _____			
12. TOTAL FILTRATION OF PRIMARY BEAM (mm Al equiv.)			
A. BEFORE MODIFICATION _____			
B. AFTER MODIFICATION _____			
13. ROENTGEN OUTPUT AT END OF PORTER CONE IN r/hr.			
A. BEFORE MODIFICATION _____			
B. AFTER MODIFICATION _____			
14. IS X-RAY UNIT OPERABLE AT LEAST 6 FEET FROM TUBE HEAD			
0. NO _____ 1. YES _____			
15. TIME			
SURVEY BEGAN _____ SURVEY ENDED _____ DIFFERENCE IN MINUTES _____			
16. DATE OF SURVEY			
(MONTH/DAY/YEAR) _____			
17. FURTHER CONSULTATION RECOMMENDED			
0. NO _____ 1. YES (SEE REMARKS) _____			
18. CODE NUMBER OF SURVEYOR			

PHS-9897-1
REV. 1-67

Form Approved
Budget Bureau No. 50-5723

Figure 17. Dental X-ray Protection Survey Report, side 1

PHS-3097-1
REV. 1-67 (PAGE 2)

Radiological Health Data and Reports

Technical Notes

Preliminary Survey of X-Ray Producing Devices in Kansas Schools, 1968

Leo W. Spencer, Jr.¹

During recent years, a growing interest has developed in the extent of possession and use of radiation-producing devices in schools. In 1968, personnel of the Kansas State Department of Health, in cooperation with the Kansas State Department of Public Instruction, distributed a questionnaire in an effort to determine the magnitude of this situation. The questionnaire, in the form of a registration sheet (figure 1), was sent to 1,530 science instructors in 755 schools listed in the "1967-68 Science Directory for Kansas Schools."

The data compiled from questionnaires returned by 92 percent of the schools are presented in table 1. In view of the large number of demonstration x-ray tubes, and the information published by the Bureau of Radiological Health (1) on Crookes tubes, it was decided that an onsite inspection of selected schools should be conducted. (Radiographic machines and shoe-fitting fluoroscopes were investigated immediately upon being reported.)

Survey method

The existing heavy workload of the Radiological Health Section necessitated that a limited preliminary survey of 2- weeks duration be made. A selection of 22 schools was made, based on determination of those thought to have the greatest potential for student exposure, or those indicating presence of radiographic machines,

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Table 1. Distribution of radiation-producing devices reported by Kansas schools

Device	Number of devices	Number of schools
X-ray diffraction.....	2	2
Radiographic.....	4	4
Hand-held fluoroscope.....	22	20
Shoe-fitting fluoroscope.....	2	2
Demonstration x-ray tube.....	62	50
Particle accelerator.....	7	7
Electron microscope.....	1	1
Van de Graaff generator.....	150	147
Crookes tube.....	240	137
Geiger tube.....	533	129
Teles coils.....	150	117
Radar.....	9	5
Luminous devices.....	10	8
High voltage vacuum tubes.....	50	19
Isotopes.....	—	179
Laser.....	4	3

* Includes all microwave devices.

* Number of isotopes not requested.

shoe-fitting fluoroscopes, x-ray diffraction machines, electron microscopes, and/or hand-held fluoroscopes.

In order to determine what protective measures might be necessary, the following information was collected:

- (1) accuracy of the replies to the questionnaire/registration form;
- (2) output from each device;
- (3) workload of each device (minutes of exposure per year per student);
- (4) operating procedure for each device:
 - (a) setup of equipment,
 - (b) positions of the student and teacher in relation to the equipment, and
 - (c) voltages applied.

A Nucor model CS-40 survey meter and a Victoreen model 570 R-Meter were used to measure exposure rates.

Kansas State Department of Public Instruction
in cooperation with
Kansas State Department of Health

REGISTRATION OF SCHOOL RADIATION MACHINES FORM

Do not write in this space

School Dist.

County

City

1 2 3 4

5 6 7

8 9 10 11

Radiation Machines, etc.	Number
X-ray diffraction machines	(12) —
X-ray radiographic machines	(13) —
Hand-held demonstration fluoroscopes	(14) —
Shoe-fitting fluoroscopes.	(15) —
Demonstration x-ray tubes.	(16) —
Particle accelerators	(17) —
Electron microscopes	(18) —
Van de Graaff Accelerators	(19) —
Crookes tubes.	(20) —
Geissler tubes	(21) —
Tesla coils	(22) —
Army (or other) surplus:	
Radar	(23) —
Luminous devices	(24) —
High voltage* vacuum tubes	(25) —
Other (specify) _____	(26) —
Do you ever use radioactive isotopes? (27) 1. <u>Yes</u> 2. <u>No</u>	

Date _____ Signature _____

*20,000 volts or more (0.58 cm spark gap between spheres 2.5 cm. in diameter, or 1.75 cm spark gap between needle points)

Form RH-51 (1168)

Figure 1. Registration form for school radiation machines (Inquiry concerning lasers was omitted from this form but information was requested in cover letter)

Survey results

A check of the information on the returned form registration revealed an overestimation of the actual number of devices in Kansas schools, since many teachers are unfamiliar with the identity or names of the devices listed (table 2). Some devices were found to be in storage without anyone's knowledge.

Table 2. Accuracy of replies to questionnaire

Device	Number reported	Number on hand	Number in use
X-ray diffraction	2	0	0
Radiographic	4	3	0
Hand-held fluoroscope	14	9	2
Flow-fitting fluoroscope	2	1	0
Demonstration x-ray tube	14	14	3
Electron microscope	1	0	0
Crookes tube	21	21	12

The low use rate of the devices is the result of three factors: (1) some teachers do not make use of equipment purchased by their predecessors, (2) some teachers do not wish to operate x-ray producing devices, and (3) the trend in teaching high school science is to present basic scientific principles, rather than applications of technology.

The data on three demonstration x-ray tubes and four Crookes tubes which produced measurable exposure rates are shown in table 3. The table shows that the maximum exposure to any student was calculated to be 750 mR. This exposure was to the hands of 10 high school students over a school year and represented the only situation in which dose to a student could have exceeded the maximum permissible dose of 500 mrem/a as recommended in NCRP report No. 32 (2).

The survey indicates that the amount of unnecessary exposure received by a student in school work is significantly smaller than that which, as a patient, he could receive from an unfiltered and uncollimated diagnostic x-ray machine. Therefore, a school survey program based on the following recommendations would not command as high a priority as the location and correction of faulty diagnostic x-ray equipment.

Recommendations

As a result of the information obtained in this survey, the Radiological Health Section will

Table 3. Exposure data*

Device	Use	Output at 6 in from target (R/h)	Use time (min/a)	Student distance (ft)	Student exposure (mR)
Demonstration x-ray tube	Hand fluoroscopy	45	1	0.5	750
Demonstration x-ray tube	Hand fluoroscopy	4.5	1	.5	75
Demonstration x-ray tube	Capacitor discharge	45	1	9.0	.8
Crookes tube	Kinetic energy	.60	1	3.0	24
Crookes tube	Magnetic deflection	.000	1	3.0	2.0
Crookes tube	Magnetic deflection	.012	3	3.0	2.0
Crookes tube	Fluorescence	.015	3	3.0	2.0

* Nine Crookes tubes did not register a measurable exposure rate on the CR-40. Of these, one tube was operated at 40 kV, another at 20 kV, and the rest at less than 10 kV.

^b Per student.

^c The 0.5 mR exposure is achieved by standing in a position that takes advantage of the shadow produced by the back side of the tube anode.

^d The 24 mR exposure occurs at a position which is incorrect for observation of the experiment.

visit the remaining schools which have indicated possession of both a demonstration x-ray tube and a hand-held fluoroscope and recommend discontinuance of hand fluoroscopy. The 35 schools that have indicated possession of demonstration x-ray tubes will be contacted by telephone to verify, locate, and arrange for a survey of those in use. Demonstration x-ray tubes which are capable of being energized will be registered by school location so that an inquiry can be made every 2 years to determine whether the tubes are being activated. In addition, all schools will be advised by letter that:

(1) the Kansas State Department of Health shall be notified of the location of all demonstration x-ray tubes and x-ray machines, and

(2) that Crookes tubes can produce x-rays, but can be operated safely if used for less than one minute per year, a distance greater than 6 feet from the tube is maintained, or a potential of less than 20 kV is used.

REFERENCES

- (1) PUBLIC HEALTH SERVICE, DIVISION OF REGIONAL OPERATIONS. Radiation Sources in Secondary Schools, ORO 69-5. National Technical Information Service, Springfield, Va. 22151 (1969).
- (2) NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. Radiation Protection in Educational Institutions, NCRP Report No. 32. 4000 Brandywine St, N.W., Washington, D.C. 20016 (July 1, 1966).

SECTION I. MILK AND FOOD

Milk Surveillance, July 1970

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radioactive contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Bureau of Radiological Health and the Bureau of Foods, Pesticides and Product Safety, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 16 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of, nuclear fission become incorporated in milk (1). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent abundance of the element potassium (2), resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostron-



Figure 1. Milk sampling networks in the Western Hemisphere

tium and radionesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2-standard deviations (2σ), for these concentrations are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (5) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (4).

The most recent study was conducted during May–July 1970, with 28 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89,

strontium-90, iodine-131, cesium-137, and barium-140 (5). Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 12 participated in the experiment.

The accuracy results of this experiment are shown in table 1. In general, considerable improvement is needed, especially in the accuracy measurements. Keeping these possible differences in mind, integration of the data from the various networks can be undertaken.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Table 1. Distribution of mean results, quality control experiment

Isotope and level	Number of laboratories in each category			Total
	Acceptable ($X \leq \bar{X} \pm 2\sigma$)	Warning level ($X \pm 2\sigma < X < \bar{X} \pm 3\sigma$)	Unacceptable ($X > \bar{X} \pm 3\sigma$)	
Strontium-89—High (250 pCi/liter).....	7 (44%)	1 (6%)	8 (50%)	16
Low (15 pCi/liter).....	11 (69%)	3 (19%)	2 (12%)	16
Strontium-90—Intermediate (70.4 pCi/liter).....	13 (57%)	4 (17%)	6 (26%)	23
Low (32.0 pCi/liter).....	5 (25%)	4 (20%)	11 (55%)	20
Iodine-131—High (307 pCi/liter).....	18 (67%)	2 (7%)	7 (26%)	27
Low (40 pCi/liter).....	16 (64%)	3 (12%)	6 (24%)	25
Cesium-137—High (250 pCi/liter).....	20 (74%)	3 (11%)	4 (15%)	27
Low (250 pCi/liter).....	17 (66%)	5 (19%)	4 (15%)	26
Barium-140—High (302 pCi/liter)*.....	18 (67%)	2 (7%)	7 (26%)	27
Low (33 pCi/liter).....	23 (92%)	0	2 (8%)	25

* Known concentrations.

The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A previous article (6) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short-time periods, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. An analysis (7) of raw and pasteurized milk samples collected from January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses (8). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have

been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (9). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1-5 pCi/liter for levels <50 pCi/liter; 5-10% for levels ≥50 pCi/liter;
Strontium-90	1-2 pCi/liter for levels <20 pCi/liter; 4-10% for levels ≥20 pCi/liter;
Iodine-131 } Cesium-137 } Barium-140 }	4-10 pCi/liter for levels <100 pCi/liter; 4-10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <25 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity

in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance to Federal agencies in the formulation of radiation standards.

Radiation Protection Guides (8,9)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result due to exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 2 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (3).

In the absence of specific dietary data, one can use milk as the indicator food item for routine surveillance. Assuming a 1-liter per day intake of milk, one can utilize the graded approach of

daily intake on the basis of radionuclide content in milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Protective Action Guides (10,11)

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1 or 2-year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 3 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier (3). Also given in table 3 are milk concentrations for each of the radionuclides considered, in the absence of others, which, if attained after an

Table 2. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Nuclide	Critical organ	RPG for individual in the general population (rad/a)	Guidance for suitable samples of exposed population group ^a				
			RPG (rad/a)	Corresponding continuous daily intake (pCi/day)	Range I ^b (pCi/d·y)	Range II ^b (pCi/day)	Range III ^b (pCi/day)
Strontium-90	Bone	• 1.5	0.5	• 2,000	0-200	200-2,000	2,000-20,000
	Bone marrow	• .5	.17				
Strontium-90	Bone	• 1.5	.5	• 200	0-20	20-200	200-2,000
	Bone marrow	• .5	.17				
Iodine-131	Thyroid	1.5	.5	100	0-10	10-100	100-1,000
Cesium-137	Whole body	.5	.17	3,600	0-360	360-3,600	3,600-36,000

^a Suitable samples which represent the limiting conditions for this guidance are: strontium-90, strontium-90—general population; iodine-131—children 1 year of age; cesium-137—infants.

^b Based on an average intake of 1 liter of milk per day.

^c A dose of 1.5 rad/a to the bone is estimated to result in a dose of 0.5 rad/a to the bone marrow.

^d For strontium-90 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.

^e The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

Table 3. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-90	Bone marrow	10 in first year; total dose not to exceed 15 ^{a,b}	3 in first year; total dose not to exceed 5 ^{a,b}	• 1,110,000
Strontium-90	Bone marrow			• 51,000
Cesium-137	Whole body			• 720,000
Iodine-131	Thyroid	50	10	• 90,000

^a The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.

^b Total dose from strontium-90 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.

^c These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.

^d This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

acute incident, would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the pasture-cow-milk-man pathway, as well as an estimate of the intake prior to reaching the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in retrospective manner.

Data reporting format

Table 4 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. (The relationship between the PMN stations and State stations is shown in figure 2.) The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 4, surveillance results are given for strontium-90, iodine-131, and cesium-137 for July 1970 and the 12-month period, August 1969 to July 1970. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 4 since levels at the great majority of the stations for July 1970 were below the respective practical reporting levels. Table 5 gives monthly averages for those stations at which strontium-89 was detected.

Iodine-131 results are included in table 4, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 2), levels in milk for this radionuclide are of particular public health interest. In general, the prac-

Table 6. Concentrations of radionuclides in milk for July 1970 and 12-month period, August 1970 through July 1970

Sampling location		Type of sample	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average	12-month average	Monthly average	12-month average	Monthly average	12-month average
United States:								
Ala:	Montgomery	P	3	6	0(3)	0	0(1)	
Alaska:	Palmer	P	7	1	0	0	15	
Ariz:	Phoenix	NA	1	1	0	0	0	
Ark:	Little Rock	P	13	12	0(3)	0	10(3)	
Calif:	Sacramento	NA	1	1	0	0	0	
	San Francisco	P	6	2	0(3)	0	0(3)	
	Del Norte	P	19	19	0	0	15	
	Pruned	P	2	2	0	0	0	
	Humboldt	P	3	3	0	0	0	
	Los Angeles	P	3	3	0	0	0	
	Merced	P	4	3	0	0	0	
	Sacramento	P	4	3	0	0	0	
	San Diego	P	3	3	0	0	0	
	Santa Clara	P	2	2	0	0	0	
	Shasta	P	4	3	0	0	0	
	Sonoma	P	3	3	0	0	0	
Calif:	Danvers	P	3	3	0	0	0	
	West	P	8	8	0(2)	0	0(2)	
	Northwest	R	(a)	(a)	0(2)	0	0(2)	
	East	R	(a)	(a)	0	0	0	
	Southwest	R	(a)	(a)	0	0	0	
	South central	R	(a)	(a)	0	0	0	
	Southwest	R	(a)	(a)	0	0	0	
Conn:	Hartford	R	(a)	(a)	0	0	0	
	Central	P	8	8	0(2)	0	22(2)	
	Wilmington	P	7	7	0(2)	0	23(2)	
Del:	Washington	P	13	9	0	0	25	
D.C.:	Washington	P	8	7	0(2)	0	7(2)	
Fla:	Tampa	P	7	6	0(2)	0	65(2)	
	West	R	9	11	0	0	37	
	North	R	13	11	0	0	27	
	Northwest	R	6	7	0	0	70	
	Central	R	3	7	0	0	123	
	Tampa Bay area	R	5	7	0	0	70	
	Southwest	R	7	7	0	0	130	
Ga:	Atlanta	P	8	10	0(4)	0	18(4)	
Hawaii:	Bozeman	P	4	2	0	0	0	
Idaho:	Idaho Falls	P	7	3	0	0	20	
Ill:	Chicago	P	3	3	0	0	17	
Ind:	Indianapolis	P	7	9	0	0	11	
	Northwest	P	14	9	0	1	20	
	Southwest	P	11	10	0	0	10	
	Central	P	19	9	0	0	0	
	Southwest	P	10	11	0	0	15	
	Northwest	P	15	10	0	0	20	
Iowa:	Des Moines	P	6	6	0(2)	0	10(2)	
	Iowa City	P	NA	8	NA	0	NA	
	Des Moines	P	11	7	0(4)	0	13	
	Spencer	P	5	4	0	0	12	
Kans:	Fredericksburg	P	NA	NA	NA	NA	NA	
	Wichita	P	6	8	0	0	11	
	Colleyville	P	NA	8	0	0	0	
	Dodge City	P	NA	7	0	1	0	
	Paoli City, Neb	R	NA	9	0	0	0	
	Hays	R	NA	8	0	0	0	
	Kansas City	P	NA	9	0	0	0	
	Topeka	P	NA	9	0	0	11	
	Wichita	P	NA	7	0	0	0	
Ky:	Louisville	P	9	8	0(2)	0	3(2)	
La:	New Orleans	P	17	15	0(2)	0	20(2)	
Maine:	Portland	P	12	11	0	0	22	
Mid:	Baltimore	P	8	8	0	0	19	
Mass:	Boston	P	11	10	0	0	26	
Mich:	Detroit	P	10	8	0	0	15	
	Grand Rapids	P	10	9	0	0	12	
	Bay City	P	7	7	0	0	16	
	Charlevoix	P	11(2)	12	0(3)	0	24(3)	
	Detroit	P	10	8	0	0	16	
	Grand Rapids	P	10	8	0	0	12	
	Lansing	P	10(2)	9	0(2)	0	14(2)	
	Marquette	P	14(2)	13	0(2)	1	26(2)	
	Monroe	P	7	6	0(2)	0	24(2)	
Minn:	South Haven	P	3(2)	3	0	0	14(4)	
	Minneapolis	P	14	10	0	0	23	
	Bemidji	P	6	13	0	0	15	
	Manly	P	3	3	0	0	11	
	Rochester	P	4	7	0	0	17	
	Duluth	P	17	16	0	0	25	
	Worthington	P	4	5	0	0	14	
	Minneapolis	P	7	10	0	0	21	
	Fergus Falls	P	4	7	0	0	18	
	Little Falls	P	15	9	0	0	22	

See footnotes at end of table.

Table 4. Concentrations of radionuclides in milk for July 1970 and 12-month period August 1970 through July 1970—continued

Sampling location		Type of sample	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average	12-month average	Monthly average	12-month average	Monthly average	12-month average
United States—Continued								
Miss:	Jackson	P	11	12	0	0	31	1
Miss:	Kansas City	P	10	8	0(2)	0	0(2)	8
Miss:	St. Louis	P	14	8	0(2)	0	4(2)	3
Mont:	Helena	P	5	5	0(2)	0	14(2)	0
Nebr:	Omaha	P	5	6	0(2)	0	11(2)	1
Nebr:	Las Vegas	P	7	1	0	0	0	0
N.H.:	Manchester	P	12	8	0	0	23	1
N.J.:	Trenton	P	11	3	0	0	0	0
N. Mex.:	Albuquerque	P	10	7	0(2)	0	0(2)	0
N.Y.:	Buffalo	P	13	10	0	0	25	1
N.Y.:	New York City	P	9	7	0	0	23	1
N.Y.:	Syracuse	P	7(2)	4	0(0)	0	0	0
N.Y.:	Albany	P	0(2)	0	0(4)	0	0	0
N.Y.:	Buffalo	P	14	6	0	0	45	0
N.Y.:	Massena	P	9	7	0(4)	0	0	0
N.Y.:	Newburg	P	15	3	NS	0	NS	0
N.Y.:	New York City	P	9	11	0	0	12	1
N.C.:	Spartanburg	P	11	9	0	0	18	1
N. Dak.:	Minot	P	7	8	0(2)	0	4(2)	4
Ohio:	Cincinnati	P	11	9	0	0	26	7
Ohio:	Cleveland	P	6	6	0(2)	0	7(2)	7
Okla.:	Oklahoma City	P	NS	NS	NS	NS	NS	NS
Okla.:	Enid	P	NS	NS	NS	NS	NS	NS
Okla.:	Tulsa	P	NS	NS	NS	NS	NS	NS
Okla.:	Lawton	P	NS	NS	NS	NS	NS	NS
Okla.:	Ardenmore	P	NS	NS	NS	NS	NS	NS
Okla.:	Portland	P	7	4	0(2)	0	10(2)	6
Okla.:	Bellevue	P	NA	3	0	0	19	2
Okla.:	Coco Bay	P	6	3	0	0	30	13
Okla.:	Enid	P	4	3	0	0	0	6
Okla.:	Medford	P	3	2	0	0	25	10
Okla.:	Portland composite	P	4	4	0	0	18(2)	8
Okla.:	Portland local	P	4	4	0	0	13(2)	3
Okla.:	Blanchard	P	NA	2	0	0	0	0
Pa.:	Pittsburgh	P	12	9	0	0	17	12
Pa.:	Philadelphia	P	14	11	0	0	27	10
Pa.:	Dauphin	P	NS	7	NS	3	X	11
Pa.:	Erie	P	25	12	0	6	36	26
Pa.:	Philadelphia	P	7	8	0	4	13	12
Pa.:	Pittsburgh	P	12	12	0	2	35	20
R.I.:	Providence	P	10	9	0	0	27	16
S. Dak.:	Charleston	P	7	10	0	1	19	21
Tenn.:	Rapid City	P	8	9	0	0	14	4
Tenn.:	Chattanooga	P	10	9	0	0	10	12
Tenn.:	Memphis	P	8	9	0	0	14	6
Tenn.:	Chattanooga	P	10	11	0	0	14	13
Tenn.:	Clinton	P	13	13	0(2)	0	26	13
Tenn.:	Knoxville	P	8	8	0(2)	0	19	7
Tenn.:	Nashville	P	7	8	0(2)	0	15	8
Tenn.:	Fayetteville	P	11	13	0(2)	0	16	14
Tenn.:	Austin	P	3	3	0	0	12	4
Tenn.:	Dallas	P	7	6	0	0	11	7
Tenn.:	Amarillo	R	NS	NS	NS	NS	NS	NS
Tenn.:	Corpus Christi	R	NS	NS	NS	NS	NS	NS
Tenn.:	El Paso	R	NS	NS	NS	NS	NS	NS
Tenn.:	Fort Worth	R	NS	NS	NS	NS	NS	NS
Tenn.:	Harlingen	R	NS	NS	NS	NS	NS	NS
Tenn.:	Houston	R	NS	NS	NS	NS	NS	NS
Tenn.:	Lubbock	R	NS	NS	NS	NS	NS	NS
Tenn.:	Midland	R	NS	NS	NS	NS	NS	NS
Tenn.:	San Antonio	R	NS	NS	NS	NS	NS	NS
Tenn.:	Texas	R	NS	NS	NS	NS	NS	NS
Tenn.:	Uvalde	R	NS	NS	NS	NS	NS	NS
Tenn.:	Wichita Falls	R	NS	NS	NS	NS	NS	NS
Utah:	Salt Lake City	P	3	4	0	0	17	4
Vt.:	Burlington	P	11	8	0(2)	0	18(2)	13
Vt.:	Norfolk	P	12	10	0(2)	0	14(2)	9
Wash.:	Seattle	P	5	6	0(2)	0	0(2)	4
Wash.:	Spokane	P	0	0	0(2)	0	4(2)	2
Wash.:	Spokane	R	0	0	0	0	0	7
Wash.:	Franklin County	R	NS	2	NS	0	NS	3
Wash.:	Franklin County	R	12	10	0	0	23	24
W. Va.:	Sanpoint, Idaho	R	8	6	0	0	13	11
W. Va.:	Charleston	P	NS	8	NS	0	NS	4
Wise.:	Milwaukee	P	7	7	0	0	17	10
Wyo.:	Laramie	P	4	5	0(2)	0	0(2)	1

See footnotes at end of table.

Table 4. Concentrations of radionuclides in milk for July 1970 and 12-month period August 1970 through July 1971—continued

Sampling location		Type of sample ^a	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average ^b	12-month average	Monthly average ^b	12-month average	Monthly average ^b	12-month average
Canada								
Alberta:	Calgary	P	NA		(d)		22	19
	Edmonton	P	NA		(d)		23	17
British Columbia:	Vancouver	P	NA		(d)		25	29
Manitoba:	Winnipeg	P	NA		(d)		30	25
New Brunswick:	Fredericton	P	NA		(d)		34	30
Newfoundland:	St. John's	P	NA		(d)		73	37
Nova Scotia:	Halifax	P	NA		(d)		31	19
Ontario:	Ft. William	P	NA		(d)		25	27
	Ottawa	P	NA		(d)		31	13
Ontario:	Sault Ste. Marie	P	NA		(d)		43	31
	Toronto	P	NA		(d)		8	9
	Windsor	P	NA		(d)		12	10
Quebec:	Montreal	P	NA		(d)		27	18
	Quebec	P	NA		(d)		35	27
Saskatchewan:	Regina	P	NA		(d)		19	14
	Saskatoon	P	NA		(d)		24	13
Central and South America:								
Columbia:	Bogota	P	0	1	0	0	0	3
Chile:	Santiago	P	0	0	0	0	0	2
Ecuador:	Guayaquil	P	1	0	0	0	0	0
Jamaica:	Kingston	P	3	5	0	0	55	90
Venezuela:	Caracas	P	0	2	0	0	0	0
Canal Zone:	Cristobal	P	3	1	0(3)	0	9(3)	10
Puerto Rico:	San Juan ^c	P	4	3	0(3)	0	3(3)	6
PMN network average ^c			8	7	0	0	14	8

^a P, pasteurized milk; R, raw milk.

^b When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

^c PHS Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

^d Radionuclide analysis not routinely performed.

^e The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter

Cesium-137: Colorado—25 pCi/liter

Strontium-90: New York—3 pCi/liter

Michigan—14 pCi/liter

New York—20 pCi/liter

Oregon—15 pCi/liter

Oregon—15 pCi/liter

^f This entry gives the average radionuclide concentrations for the PHS Pasteurized Milk Network stations denoted by footnote ^a.

^g Weekly samples were collected and composited for quarterly analysis of strontium-90.

NA, no analysis.

NS, no sample collected.

tical reporting level for iodine-131 is numerically equal to the upper value of Range 1 (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 25 pCi/liter in the United States for the month of July 1970 and the highest 12-month average was 19 pCi/liter (Del Norte, Calif.) representing 9.5 percent of the Federal Radiation Council radiation protection guide (table 2). Cesium-137 monthly averages ranged from 0 to 139 pCi/liter in the United States for July 1970 and the highest 12-month average was 76 pCi/liter (southeast Florida), representing 2.1 percent of the value presented in this report using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (12) and Jamaica. Io-

dine-131 results for individual samples were all below the practical reporting level.

Table 5. Strontium-90 in milk, July 1970

Sampling location	Strontium-90 (pCi/liter)
Calif: Del Norte (State)	12
Colo: Denver (PMN)	6
Ga: Atlanta (PMN)	6
Iowa: Des Moines (PMN)	6
Ky: Louisville (PMN)	6
Md: Baltimore (PMN)	6
Mass: Boston (PMN)	11
Minn: Minneapolis (PMN)	9
Mo: Kansas City (PMN)	6
Nebr: Omaha (PMN)	7
Nev: Las Vegas (PMN)	6
N.Y.: Albany (State)	5
S.C: Charleston (PMN)	7
S.Dak: Rapid City (PMN)	6
Tenn: Knoxville (State)	6
Nashville (State)	6
Tex: Dallas (PMN)	6
Wash: Spokane (PMN)	6
Chile: Santiago (PAHO)	30
Ecuador: Guayaquil (PAHO)	10
Venezuela: Caracas (PAHO)	10

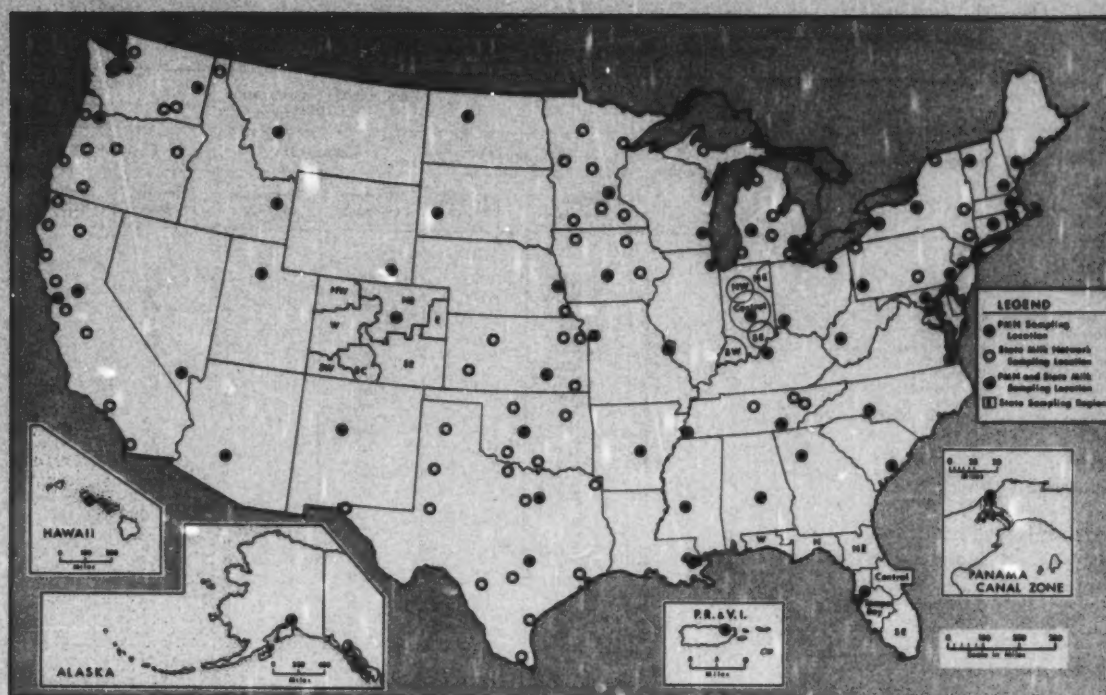


Figure 2. State and PMN milk sampling locations in the United States

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Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
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State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Nuclear Engineering
New York State Department of Environmental
Conservation

Division of Occupational and Radiological
Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

<u>Program</u>	<u>Period reported</u>	<u>Issue</u>
Connecticut Diet Study	July-December 1968 and January-June 1969	February 1970
Strontium-90 in Tri-City Diets, HASL	June-December 1969	June 1970

1. Estimated daily intake of radionuclides in California diets, April-December 1969, and January-June 1970

*Bureau of Radiological Health
California State Department of Public Health*

Since January 1964, the Bureau of Radiological Health, California State Department of Public Health, has made estimates of 4 radionuclide levels in the diets of Californians (1).

Recognizing that a "standard" or "typical" diet does not exist due to variations in individual tastes, an effort was made to select a diet which was reasonably representative of the food consumed in a given area. This objective was met by utilizing the "house" diet of a hospital in each of the 20 geographic areas of interest (figure 1).

Hospitals were chosen as the source of diet samples under the hypothesis that their diets are as "reasonably representative" as any other. General hospitals exist in each of the 20 selected geographic areas and operate with trained dietitians. There is good reason to believe that hos-

pitals utilize foods which are marketed in their respective communities. Also, working relations for entry into hospitals existed through the State Bureau of Nutrition and Hospitals.

Sampling procedure

In general, the sampling procedure is the same at each hospital. Samples are collected every 2 months at each facility. Each sample represents the edible portion of a regular meal (the standard diet) for a full 7-day week (21 consecutive meals).

After each sample is collected, it is suitably preserved and shipped to the Sanitation and Radiation Laboratory of the State Department of Public Health. Accompanying each sample is a record prepared by the dietitians indicating the types and quantities of food included.

Analytical procedures

After weighing at the laboratory, each sample is homogenized and analyzed for gamma-ray emitters, then dried and ashed prior to analysis

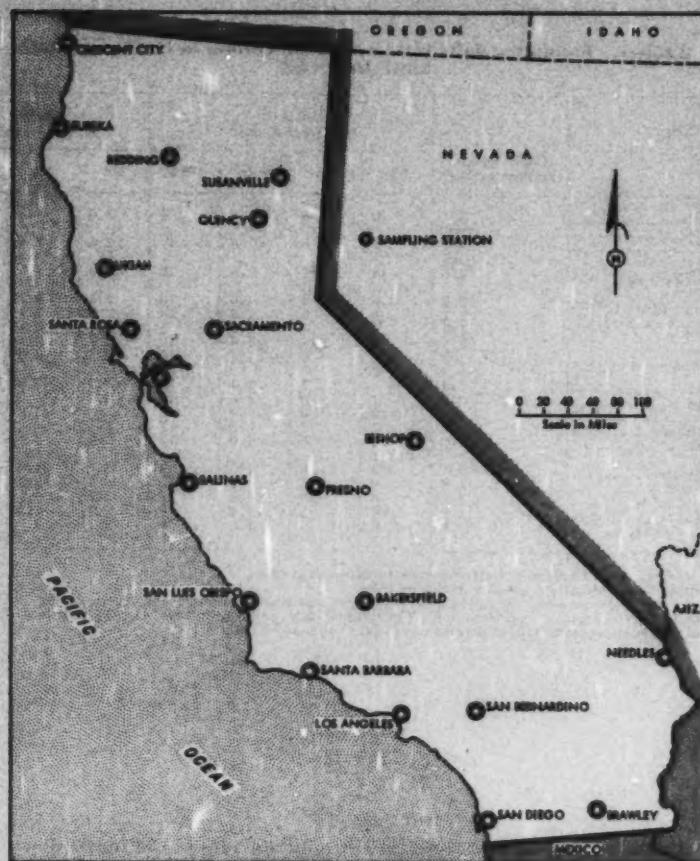


Figure 1. California diet sampling stations

for strontium-89, strontium-90, radium-226, and stable calcium, strontium, and sodium.

Data and discussion

The resultant estimates of daily intake of radionuclides in the California diets are given in table 1 (April-June 1969), table 2 (July-September 1969), table 3 (October-December 1969), table 4 (January-March 1970), and table 5 (April-June 1970).

It should be noted that levels of radioactivity were observed to be far below those levels for which consideration should be given to protective health action.

A summary of strontium-90 and cesium-137 intake trends in California diets from January 1964 through June 1970 is given in figures 2 and 3.

REFERENCE

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Recent coverage in *Radiological Health Data and Reports*:

<u>Period</u>	<u>Issue</u>
October-December 1968 and	
January-March 1969	May 1970

Table 1. Estimated daily intake of radionuclides in California diet:
April-June 1969

City	Consumption (kg/capita-day) ^b	Intake ^a (pCi/capita-day)				Intake (g/capita-day)		
		²²⁶ Ra	²³² Th	²³⁸ Pa	²³⁸ U	K ⁴⁰	Na	Ca
Bakersfield	2.1	0	6	1.8	9	2.9	4.1	1.1
Berkeley	NS							
Bishop	1.8	2	6	1.0	10	2.0	3.1	.8
Brawley	NS							
Crescent City	2.5	15	17	1.0	22	4.0	4.5	1.0
Eureka	2.2	2	8	1.5	16	2.5	4.3	.6
Fresno	2.1	0	8	1.2	22	3.2	3.1	1.6
Los Angeles	1.7	1	4	.9	5	2.1	2.1	.8
Needles	2.3	1	1	1.0	10	2.7	3.1	1.0
Quincy	2.3	6	9	1.4	16	3.3	4.0	1.1
Redding	2.2	3	7	1.4	20	3.2	3.6	1.0
Sacramento	2.7	1	8	1.0	11	2.9	3.3	1.2
Salinas	2.4	0	8	.9	12	3.1	3.6	1.0
San Bernardino	1.9	2	7	.9	7	2.1	4.2	1.0
San Diego	2.0	0	0	1.0	12	2.9	3.6	.8
San Luis Obispo	2.1	2	6	1.5	16	3.1	4.0	1.2
Santa Barbara	1.9	0	4	.5	8	2.7	2.4	.9
Santa Rosa	1.8	3	9	.9	9	2.2	2.7	1.1
Seaside	1.6	4	5	1.2	8	2.2	2.9	.9
Ukiah	2.1	3	5	1.5	6	3.1	3.7	1.2

^a Based on analyses of Hospital Standard Diets located in listed cities.
^b Kilograms of food per person per day in this diet.
^c Me-ganese-54, strontium-90, and cerium-141-144 were less than their reporting levels during this period (manganese-54, 7 pCi/capita-day; strontium-90, 7 pCi/capita-day; and cerium-141-144, 10 pCi/capita-day).
^d Natural potassium contains 0.0119 percent of radioactive potassium-40.

Table 2. Estimated daily intake of radionuclides in California diet:
July-September 1969

City	Consumption (kg/capita-day) ^b	Intake ^a (pCi/capita-day)							Intake (g/capita-day)		
		²²⁶ Ra	²³² Th	²³⁸ Pa	²³⁸ U	¹³⁷ Ba-La	⁹⁰ Y-Nb	⁵⁴ Mn	K ⁴⁰	Na	Ca
Bakersfield	1.8	3	5	1.4	8	0	0	1	2.5	3.3	1.1
Berkeley	NS										
Bishop	1.6	0	5	1.1	7	0	0	4	2.5	1.8	.7
Brawley	2.1	1	6	.4	14	5	0	1	3.3	3.2	0.8
Crescent City	2.0	9	16	.9	16	0	0	0	3.4	4.2	1.2
Eureka	2.2	1	8	1.4	10	0	0	0	2.9	3.8	.9
Fresno	2.2	2	5	.8	11	0	0	1	3.2	2.0	1.1
Los Angeles	2.1	2	10	2.3	10	0	0	5	3.2	3.4	1.2
Needles	2.3	3	8	1.2	7	0	0	5	2.7	2.8	1.5
Quincy	2.3	3	6	1.8	3	0	0	0	3.2	2.8	1.0
Redding	2.0	8	10	1.7	7	0	0	3	2.6	3.7	1.1
Sacramento	2.6	2	8	2.2	0	0	4	2	3.4	5.0	1.5
Salinas	2.4	9	4	3.2	0	0	8	9	3.4	6.0	0.8
San Bernardino	2.2	1	3	.9	2	0	3	10	3.5	4.4	.5
San Diego	1.9	7	6	2.5	7	0	0	4	3.2	4.2	1.9
San Luis Obispo	1.9	1	7	2.1	0	0	1	9	2.9	4.2	1.5
Santa Barbara	1.7	2	5	.4	10	0	0	2	2.5	1.1	1.1
Santa Rosa	1.6	3	5	.2	7	0	0	1	2.0	2.9	1.3
Seaside	1.7	4	1	.9	5	0	0	2	2.1	2.1	.6
Ukiah	1.8	0	5	.9	7	0	1	2	2.8	2.0	1.2

^a Based on analyses of Hospital Standard Diets located in listed cities.
^b Kilograms of food per person per day in this diet.
^c Cerium-141-144 was less than its respective reporting level of 10 pCi/capita-day during this period.
^d Natural potassium contains 0.0119 percent of radioactive potassium-40.
 NS, no sample.

Table 3. Estimated daily intake of radionuclides in California diet*
October-December 1969

City	Consumption (kg/capita- day) ^b	Intake ^a (pCi/capita-day)						Intake (g/capita-day)		
		²³⁸ U	²³² Th	²²⁶ Ra	¹³⁷ Cs	⁹⁰ Sr- ⁹¹ Nb	⁵⁴ Mn	K ⁴⁰	Na	Ca
Bakersfield	2.1	0	15	1.5	0	4	2	3.3	4.3	1.3
Bakersfield	NS									
Bakersfield	1.7	0	5	1.5	0	0	11	3.3	2.9	1.2
Bakersfield	1.4	0	4	1.3	2	4	6	1.8	2.7	1.2
Bakersfield	1.3	0	5	1.3	6	4	4	3.0	3.9	1.1
Bakersfield	2.3	1	7	1	5	0	9	2.0	4.0	1.9
Bakersfield	1.9	1	7	1	5	0	9	3.3	2.7	1.2
Bakersfield	3.0	0	4	1	9	0	13	3.0	3.3	1.9
Bakersfield	3.3	2	5	1	7	0	10	2.8	2.0	1.1
Bakersfield	2.3	4	5	1	11	0	12	3.0	2.8	1.9
Bakersfield	2.6	0	20	3	2	2	13	3.2	3.4	1.7
Bakersfield	2.7	0	7	1	5	4	4	3.3	4.5	1.3
Bakersfield	2.4	1	7	1	10	0	7	3.4	6.1	1.9
Bakersfield	3.2	4	6	1	6	0	5	3.5	4.1	1.0
Bakersfield	3.0	0	7	1	16	5	13	3.0	3.8	1.8
Bakersfield	2.6	1	10	2	12	0	17	3.6	4.1	1.3
Bakersfield	NS									
Bakersfield	2.0	0	6	2	3	4	7	3.5	3.2	0.9
Bakersfield	1.5	2	3	0	6	0	7	3.1	2.3	1.1
Bakersfield	1.9	1	5	1	0	2	8	3.8	3.6	1.5

- * Based on analysis of Hospital Standard Diets located in listed cities.
 * Kilograms of food per person per day in this diet.
 * Barium-lanthanum-140 and cerium-141-144 were less than their respective reporting levels of 5 pCi/capita-day and 10 pCi/capita-day during this period.
 * Natural potassium contains 0.0119 percent of radioactive potassium-40.
 NS, no sample.

Table 4. Estimated daily intake of radionuclides in California diet*
January-March 1970

City	Consumption (kg/capita- day) ^b	Intake ^a (pCi/capita-day)						Intake (g/capita-day)		
		²³⁸ U	²³² Th	²²⁶ Ra	¹³⁷ Cs	⁹⁰ Sr- ⁹¹ Nb	⁵⁴ Mn	K ⁴⁰	Na	Ca
Bakersfield	2.1	1	4	1.5	27	0	0	3.6	5.3	0.8
Bakersfield	NS									
Bakersfield	1.7	3	4	1.7	9	0	7	2.0	2.0	1.1
Bakersfield	2.1	3	6	1.2	1	2	6	2.5	3.8	1.2
Bakersfield	2.8	5	14	1.7	30	0	0	3.8	3.4	1.4
Bakersfield	2.3	5	6	1.1	10	0	4	2.9	4.0	1.6
Bakersfield	2.1	1	6	1.0	7	0	5	3.2	2.2	1.2
Bakersfield	2.2	3	5	1.0	9	1	12	3.1	3.9	1.8
Bakersfield	2.3	6	5	1.7	13	0	1	2.5	2.6	1.8
Bakersfield	1.9	2	4	1.0	7	0	3	2.8	2.9	1.6
Bakersfield	2.7	3	6	1.5	5	3	12	4.0	3.3	1.3
Bakersfield	2.6	0	11	1.6	8	0	12	3.6	4.6	1.1
Bakersfield	2.4	2	6	1.0	7	0	4	3.7	6.5	1.0
Bakersfield	2.1	13	6	1.8	8	0	8	4.4	3.4	1.1
Bakersfield	2.2	5	6	1.0	9	0	9	3.3	3.3	1.8
Bakersfield	2.3	1	5	1.5	5	0	6	3.2	4.2	1.0
Bakersfield	2.3	4	6	1.1	13	2	9	3.0	3.1	1.7
Bakersfield	2.2	3	5	1.3	5	0	10	3.0	4.2	1.2
Bakersfield	1.7	2	7	1.1	7	2	7	2.5	3.0	1.1
Bakersfield	1.7	2	6	1.0	12	0	9	1.8	2.3	1.1

- * Based on analysis of Hospital Standard Diets located in listed cities.
 * Kilograms of food per person per day in this diet.
 * Barium-lanthanum-140 and cerium-141-144 were less than their respective reporting levels of 5 pCi/capita-day and 10 pCi/capita-day during this period.
 * Natural potassium contains 0.0119 percent of radioactive potassium-40.
 NS, no sample.

Table 2. Estimated daily intake of radionuclides in California diet*
April-June 1970

City	Concentration ($\mu\text{Ci}/\text{vegetable}-\text{day}$)	Intake ($\mu\text{Ci}/\text{vegetable}-\text{day}$)							Intake ($\mu\text{Ci}/\text{vegetable}-\text{day}$)		
		Na	Na	Na	Na	Na	Na	Na	Na	Na	Na
San Francisco	2.5	0	8	1.1	0	7	12	3.1	6.6	1.1	
San Francisco	1.5	2	0	1.1	1	2	12	2.5	2.3	1.0	
San Francisco	2.3	1	0	2.4	0	2	12	2.7	3.4	1.4	
San Francisco	2.4	1	14	1.9	2	4	7	3.4	5.6	.9	
San Francisco	2.5	0	0	1.9	0	0	14	2.0	4.4	1.0	
San Francisco	2.5	1	4	1.7	0	0	12	2.9	3.3	1.0	
San Francisco	2.1	0	4	1.5	1	3	14	2.7	3.6	.8	
San Francisco	2.3	0	0	1.7	0	10	12	2.6	3.1	.7	
San Francisco	2.5	2	2	.8	0	1	10	2.5	3.3	.7	
San Francisco	2.5	0	10	1.5	2	2	10	4.2	3.7	1.4	
San Francisco	2.5	0	0	1.5	0	0	14	2.5	4.0	1.3	
San Francisco	2.7	0	0	1.4	0	0	14	2.9	4.9	.7	
San Francisco	2.9	1	0	1.0	0	5	10	3.1	4.5	1.1	
San Francisco	2.1	1	5	1.3	1	2	2	2.5	3.6	.8	
San Francisco	2.5	1	10	2.2	7	0	10	2.7	6.9	.9	
San Francisco	2.5	1	0	1.5	2	2	14	2.9	3.0	1.3	
San Francisco	1.8	0	7	1.3	0	0	10	1.9	3.2	.9	
San Francisco	1.9	0	4	1.0	0	1	10	1.9	3.2	.7	
San Francisco	2.2	0	0	1.1	0	7	10	2.4	3.7	1.5	

- * Based on analysis of Hospital Standard Diet located in listed cities.
- * Concentration of food per person per day in this diet.
- * Sodium-24, sodium-22 and sodium-23 were less than their respective reporting levels of 5 $\mu\text{Ci}/\text{vegetable}-\text{day}$ and 10 $\mu\text{Ci}/\text{vegetable}-\text{day}$ during this period.
- * Natural potassium contains 0.0119 percent of radioactive potassium-40.
- * Na, no sample.

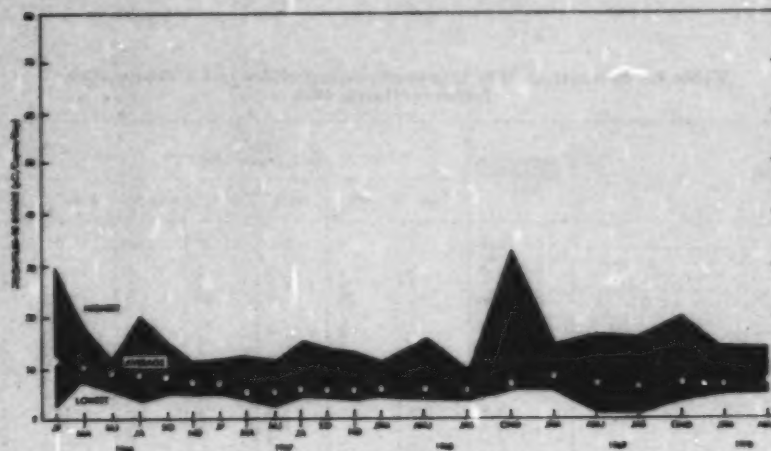


Figure 2. Averages and ranges of daily Strontium-90 in California diets
1968-June 1970

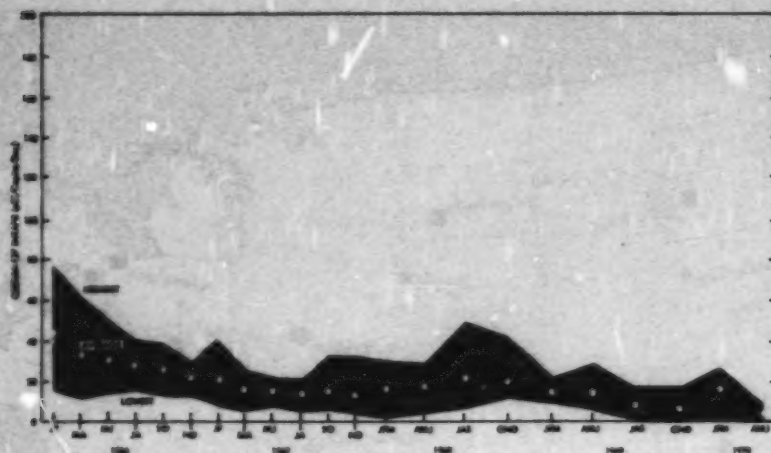


Figure 2. Average and ranges of daily cesium-137 intake in California diets, 1965-June 1970

2. Radionuclides in Institutional Diet Samples, January-March 1970

*Bureau of Radiological Health and
Food and Drug Administration*

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiological surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service initiated its Institutional Diet Sampling Program in 1961 (1). This program is administered by the Bureau of Radiological Health with the assistance of the Bureau of Compliance, Food and Drug Administration.

The program was designed to provide estimates of the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. Initially, the program was conducted at eight institutions; as of January 1965, its scope had increased to boarding schools or institutions in 50 municipalities. These insti-

tutions ranged from financially well-to-do boarding schools to orphanages with severe economic limitations.

Subsequent experience with the diets of school children of various ages indicated that the number of institutions sampled could be selectively reduced. As of March 1970, 19 basic institutions and eight auxiliary institutions distributed geographically as shown in figure 1, were being sampled. The station at Denver, Colo., was discontinued in July 1969, due to difficulty in locating a new institution. Previous results showed that the daily dietary intakes of teenage girls and children from 9 to 12 years of age were comparable, while teenage boys consumed 20 percent more food per day (1,2). Consequently, estimates for boys or girls can be calculated on the basis of the dietary intakes of children.

In general, the sampling procedure is the same at each institution. Each sample represents the edible portion of the diet for a full 7-day week (21 meals plus soft drinks, candy bars, or other in-between snacks) obtained by duplicating the meals of a different individual each day. Drinking water, not included in the samples, is also sampled periodically. Each daily sample is kept frozen



Figure 1. Institutional diet sampling locations as of December 1969

until the end of the collection period and is then packed in dry ice and shipped by air express to either the Southwestern Radiological Health Laboratory, Las Vegas, Nev., the Southeastern Radiological Health Laboratory, Montgomery, Ala., or the Northeastern Radiological Health Laboratory, Winchester, Mass. A detailed description of sampling and analytical procedures was presented earlier (3).

Results

Table 1 presents the analytical results for institutional diet samples collected from January through March 1970 for children 9 to 12 years of age. The stable elements, calcium and potassium, are reported in g/kg of diet. The radionuclide concentration of these samples, reported in pCi/kg of diet, are corrected for radioactive decay to the midpoint of the sample collection period,

where applicable. Dietary intakes in g/day or pCi/day were obtained by multiplying the food consumption rate in kg/day by the appropriate concentration values. The average food consumption rate during this period was 1.94 kg/day compared to the network average of 1.87 kg/day observed from 1961 through 1969.

Strontium-90 dietary intake during this period averaged 11 pCi/day. This result falls within Range I as defined by the Federal Radiation Council (4). Cesium-137 intake averaged 13 pCi/day during this period. In general, strontium-89, iodine-131, and barium-140 concentrations were below detectable levels.

All concentrations that are less than or equal to the appropriate minimum detectable level have been reported as zero. The minimum detectable concentration is defined as the measured concentration equal to the 2-standard deviation analytical error. Accordingly, the minimum detectable limits are as follows:

Table 1. Concentration and intake of stable elements and radionuclides in institutional total diets of children (9-12 years of age), January-March 1970

Location of Institution	Month (1970)	Total weight (kg/day)	Calcium		Potassium		Strontium-89		Strontium-90		Cesium-137	
			(g/kg)	(g/day)	(g/kg)	(g/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)
Alaska: Palmer	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar	1.82	0.5	0.7	1.0	1.5	0	0	5	5	0	0
Ariz: Phoenix	Jan	1.79	0.8	1.3	1.2	2.2	0	0	0	0	0	0
	Feb	1.49			1.4	2.1			0	0	0	0
	Mar	NS										
Ark: Little Rock	Jan	1.65	0.7	1.0	1.5	2.2	NS	NS	0.10	0.13	0	0
	Feb	1.41			1.4	2.0					13	17
	Mar	1.25			1.5	1.9					14	18
Calif: Los Angeles	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar	1.21	0.3	0.4	1.0	1.3	0	0	0	0	0	0
Del: Wilmington	Jan	2.15	0.7	1.5	1.5	3.2	NS	NS	0.04	0.09	0	0
	Feb	2.22			1.5	2.4					0	0
	Mar	2.02			1.6	3.2					0	0
Fla: Tampa	Jan	1.56	0.6	0.9	1.2	1.8	NS	NS	0.06	0.12	14	22
	Feb	1.24			1.2	2.1					21	28
	Mar	1.56			1.6	2.5					13	17
Hawaii: Honolulu	Jan	2.23	0.4	1.0	1.4	3.3	0	0	0	0	11	14
	Feb	2.37			1.4	3.3			0	0	11	14
	Mar	2.43			1.3	3.2					12	15
Idaho: Idaho Falls	Jan	1.94	1.0	1.9	1.3	2.5	0	0	0.07	0.14	0	0
	Feb	1.99			1.4	2.9					14	18
	Mar	1.99			1.7	3.2					22	28
Ky: Louisville	Jan	2.52	0.6	1.6	1.6	4.1	NS	NS	0.07	0.17	11	14
	Feb	2.35			1.6	3.6					11	14
	Mar	2.52			1.7	4.2					13	17
La: New Orleans	Jan	1.98	0.6	1.1	1.4	2.8	0	0	0.07	0.13	11	14
	Feb	1.87			1.4	2.6					0	0
	Mar	1.74			1.6	2.8					0	0
Maine: Portland	Jan	1.53	0.8	1.3	1.7	2.6	NS	NS	0.11	0.18	0	0
	Feb	1.73			1.7	2.9					12	15
	Mar	1.70			1.7	3.0					19	24
Mass: Boston	Jan	2.20	0.6	1.4	1.5	3.3	NS	NS	0.06	0.11	0	0
	Feb	2.20			1.4	3.1					15	19
	Mar	2.21			1.5	3.3					12	15
Mo: St. Louis	Jan	2.29	1.0	2.1	1.6	3.7	NS	NS	0.05	0.11	0	0
	Feb	1.88			1.7	3.2					0	0
	Mar	2.23			1.8	4.0					0	0
Ohio: Cleveland	Jan	1.37	0.6	1.0	1.5	2.4	NS	NS	0.11	0.16	0	0
	Feb	1.64			1.6	2.5					19	24
	Mar	1.24			1.7	3.1					0	0
Pa: Pittsburgh	Jan	2.24	0.6	1.2	1.4	3.1	NS	NS	0.06	0.13	14	18
	Feb	2.00			1.4	2.8					11	14
	Mar	2.27			1.3	2.9					0	0
S.C: Charleston	Jan	1.58	0.8	1.4	1.5	2.3	0	0	0.06	0.14	19	24
	Feb	1.74			1.6	2.7					0	0
	Mar	1.70			1.6	2.5					0	0
S. Dak: Sioux Falls	Jan	1.53	0.6	1.0	1.4	2.4	NS	NS	0.05	0.08	0	0
	Feb	1.66			1.6	2.4					0	0
	Mar	1.55			1.7	2.6					0	0
Tex: Austin	Jan	1.70	0.8	1.4	1.7	2.8	NS	NS	0.06	0.10	0	0
	Feb	2.27			1.5	3.4					0	0
	Mar	1.51			1.4	2.1					0	0
Wash: Seattle	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar	2.22	0.5	1.1	1.5	3.3	0	0	3	6	0	0
Institutional average	Jan	1.94	0.7	1.2	1.5	2.9	0	0	6	11	5	10
	Feb	1.90			1.5	2.9					9	17
	Mar	1.97			1.5	2.9					6	13

* Since food samples were collected from two or more children who were not between the ages of 9 to 12, the sample weights and gamma analyses for this month were not used in the institutional average. All chemistry data was included in the institutional average since this analysis was a composite of three or less individual samples.

^b Composite analysis of three or less individual monthly samples.

Note: Since iodine-131 and barium-140 were not detected at most stations during this period, no provision was made for these radionuclides in the table. The one exception is as follows: February: 11 pCi/kg of iodine-131 was reported in Cleveland, Ohio.

NA, no analysis.

NS, no sample.

Strontium-89 5 pCi/kg
 Strontium-90 2 pCi/kg
 Iodine-131 10 pCi/kg
 Cesium-137 10 pCi/kg
 Barium-140 10 pCi/kg

Data from eight auxiliary stations are included in a separate table for general information (table 2). These stations do not meet the criterion that the majority of the samples are collected from children who range in age from 9-12 years. In

Table 2. Concentration and intake of stable elements and radionuclides in institutional total diets of individuals (auxiliary stations), January-March 1970

Location of Institution	Month (1970)	Total weight (kg/day)	Calcium		Potassium		Strontium-90 ^a		Strontium-90 ^a		Cesium-137	
			(g/kg)	(g/day)	(g/kg)	(g/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)
Alaska: Juneau	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar	1.21	0.4	0.5	1.8	2.2	0	0	0	0	0	0
Calif: San Francisco	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar	1.78	0	1.0	1.6	2.6	0	0	5	9	0	0
Miss: Columbia	Jan	1.98	*1.0	*2.0	1.6	3.2	*NA	*NA	*6	*16	12	26
	Feb	2.14			1.8	3.2					0	0
	Mar	1.89			1.8	2.8					0	0
Nebr: Omaha	Jan	2.16	*.9	*1.9	1.6	2.5	*NA	*NA	*5	*11	0	0
	Feb	2.19			1.6	2.5					0	0
	Mar	2.15			1.7	2.7					0	0
Nev: Carson City	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar	2.07	.7	1.5	2.6	3.2	0	0	14	29	0	0
N. Mex: Albuquerque	Jan	2.35	*1.0	*2.4	1.6	3.8	*NA	*NA	*3	*6	14	33
	Feb	2.48			1.8	3.9					0	0
	Mar	2.31			1.7	3.9					0	0
Oreg: Portland	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar	2.01	.5	1.1	1.8	3.0	0	0	2	5	0	0
Utah: Salt Lake City	Jan	2.94			1.1	3.1					0	0
	Feb	2.10			1.3	2.7					0	0
	Mar	2.09	.5	1.2	1.2	3.1	0	0	4	10	0	0
Institutional average	Jan	2.33	.7	1.4	1.6	3.4	0	0	5	11	7	15
	Feb	2.23			1.5	3.3					0	0
	Mar	2.01			1.6	3.2					0	0

^a Composite analysis of three or less individual samples.

NA, no analysis.

NS, no sample.

Note: Since iodine-131 and barium-140 were not detected at these stations during this period, no provision was made for these nuclides in this table.

order to supplement the existing environmental monitoring networks of the Bureau of Radiological Health, these eight institutions are being sampled in the same manner as the basic stations.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
April-June 1969	January 1970
July-September 1969	June 1970
October-December 1969 and Annual Summary 1969	August 1970

REFERENCES

- (1) ANDERSON, E. C., D. J. NELSON, Jr. Surveillance for radiological contamination in foods. *Amer J Public Health* 52:1391-1400 (September 1962).
- (2) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January-March 1965. *Radiol Health Data* 6:548-554 (October 1965).
- (3) PUBLIC HEALTH SERVICE, NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January-March 1968. *Radiol Health Data* 9:557-560 (October 1968).
- (4) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

SECTION II. WATER

The Public Health Service, the Federal Water Quality Administration, and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (1). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (2-4), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set

higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence¹ of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radio-logical Health Data and Reports* are listed below.

¹ Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

<u>Water sampling program</u>	<u>Period reported</u>	<u>Issue</u>
California	July-December 1968	August 1970
Minnesota	January-June 1969	January 1970
New York	January-June 1969	June 1970
Kansas	January-December 1969	September 1970
North Carolina	January-December 1967	May 1969
Radiostrontium in Tap		
Water, HASL	January-December 1969	July 1970
Washington	July 1967-June 1968	June 1969

REFERENCES

- (1) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402 (March 1963).
- (2) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

- (3) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).
- (4) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Tritium in Surface Water Network January-June 1970

*Bureau of Radiological Health
U.S. Public Health Service*

The tritium sampling network was established by the Public Health Service in May 1964 to measure and monitor tritium concentrations in major river systems in the United States and to provide surveillance at selected surface water stations downstream from nuclear facilities. The network consists of 8 stations selected from the 131 existing water pollution sampling stations operated by the Federal Water Quality Administration (FWQA); six of the stations are located downstream from nuclear facilities and two stations serve to establish baseline levels (figure 1).

Monthly composites of weekly samples are collected through the FWQA and sent to the Southeastern Radiological Health Laboratory for analysis. The analyses are carried out using liquid scintillation counting techniques described by Moghissi et al. (1-2). The minimum level of detectability is 0.2 nCi/liter.

Data for the samples collected during January-June 1970 are shown in table 1. Station averages for this period and the corresponding period of 1969 are also presented in the table. The highest concentration observed during the first 6 months of 1970 was 6.4 nCi/liter (Clinch River-Kington, Tenn.). The highest 6-month average, 2.5 nCi/liter, was also observed at the Clinch River station. Assuming that the specific activity of tritium in the body is essentially the same as that in the surface water, this average concentration corresponds to an estimated whole-body dose¹ of 0.4 mrem/a; or in terms of Federal Radiation Council guidance, less than 1 percent of the Radiation Protection Guide (170 mrem/a) for an average dose to a suitable sample of the exposed

¹ Development of the calculations to obtain this dose may be found in reference (3).

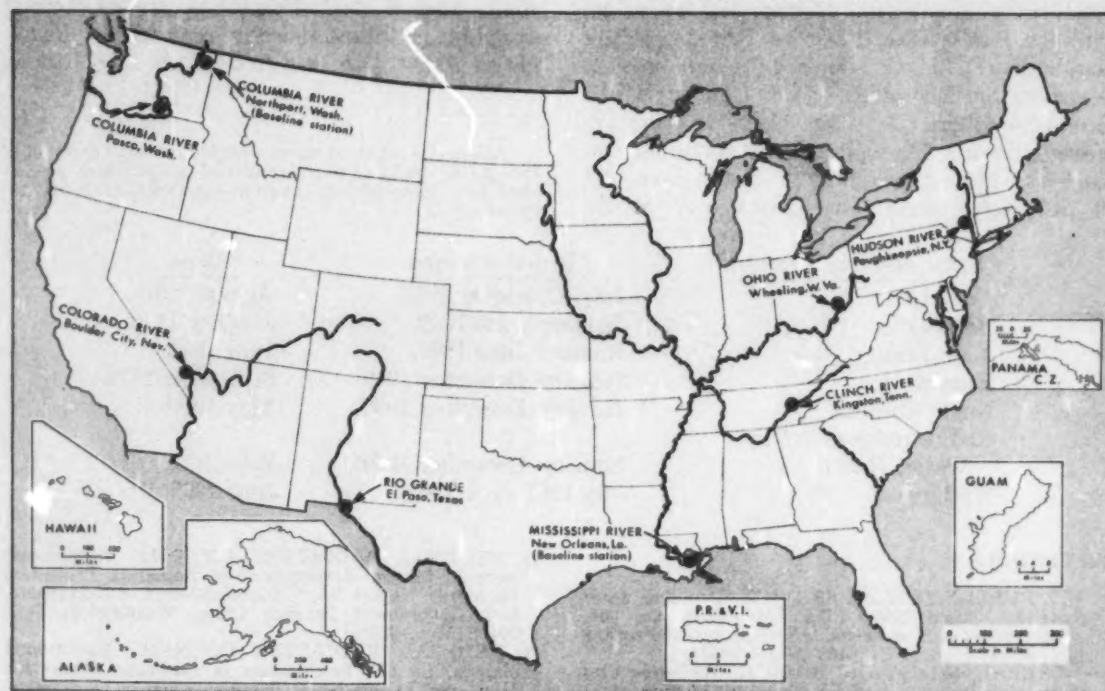


Figure 1. Sampling stations for tritium in surface waters

**Table 1. Tritium concentration in surface waters
January-June 1970**

Collection site	Concentration (nCi/liter)						January-June average for:	
	January	February	March	April	May	June	1970	1969
Clinch River: Kingston, Tenn.....	3.9±0.3	1.8±0.2	≤0	NS	6.4±0.3	1.2±0.2	2.5	14.4
Colorado River: Boulder City, Nev ^a	1.2±.2	NS	1.0±0.2	0.9±0.2	.7±.2	4.1±.3	1.6	1.4
Columbia River: Northport, Wash ^b	.5±.2	.6±.2	.8±.2	NS	NS	NS	.6	1.0
Hudson River: Poughkeepsie, N.Y.....	≤0	.5±.2	.3±.2	NS	NS	NS	.3	1.0
Mississippi River: New Orleans, La.....	≤0	≤0	NS	NS	NS	NS	0	.4
Ohio River: Wheeling, W. Va.....	≤0	≤0	≤0	≤0	≤0	.5±.2	.1	.3
Rio Grande: El Paso, Tex.....	≤0	≤0	.3±.2	.7±.2	≤0	.3±.2	.3	.1

^a All values less than or equal to the practical reporting level (0.2 nCi/liter) are reported as 0. The error reported is the 2-sigma error at the 95-percent confidence level.

^b Baseline station.

NS, no sample.

population (4). In general, the 6-month station averages were at the same level for this period as for the same period in 1969, except in the Clinch River where the 6-month average decreased from 14.4 nCi/liter in 1969 to 2.5 nCi/liter in 1970. This network will be expanded in July 1970 to include more sampling locations near operating and planned nuclear facilities.

Recent coverage in Radiological Health Data and Reports:

Period	Issue
January-June 1969	November 1969
July-December 1969	July 1970

REFERENCES

- (1) MOGHISSI, A. A., H. L. KELLEY, J. E. REGNIER, and M. W. CARTER. Low-level counting by liquid scintillation-I. tritium measurement in homogeneous systems. *Inter J Appl Rad Isotopes* 20:145 (1969).
- (2) LIEBERMAN, R. and A. A. MOGHISSI. Low-level counting by liquid scintillation—II. applications of emissions in tritium counting. *Inter J Appl Rad Isotopes* 21:319 (1970).
- (3) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters in the United States, 1966. *Radiol Health Data Rep* 9:337-339 (July 1968).
- (4) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. (May 13, 1960).

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized period-

ically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*:

<u>Network</u>	<u>Period</u>	<u>Issue</u>
Fallout in the United States and Other Areas, <i>HASL</i>	January-June 1968	October 1969
Plutonium in Airborne Particulates and Precipitation, <i>PHS</i>	April-December 1969	October 1970
Surface Air Sampling Program—80th Meridian, <i>HASL</i>	January-December 1966	October 1970

1. Radiation Alert Network July 1970

**National Air Pollution Control Administration
U.S. Public Health Service**

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Due to the density of sampling locations in three respective areas, the Rockville, Md., St Paul Island, and Adak, Alaska, stations were discontinued. Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter

products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate National Air Pollution Control Administration officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Division of Air Quality and Emission, NAPCA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during July 1970. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.



Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, July 1970

Station location		Number of samples	Air surveillance			Last profile in RHD&R	Number of samples	Precipitation			
			Gross beta radioactivity (pCi/m ³)					Total depth samples (mm)	Field estimation of deposition		
			Maximum	Minimum	Average				Number of samples	Depth (mm)	Total deposition (nCi/m ²)
Ala:	Montgomery	22	6	0	2	Oct 70					
Alaska:	Anchorage	5	0	0	0	June 70	(a)	5	102		57
	Attu Island	17	0	0	0	Nov 70	(a)				
	Fairbanks	21	1	0	1	July 70	10	37	10	37	21
	Juneau	13	5	0	2	Aug 70	8	156	8	156	0
	Kodiak	(a)				Sept 70	(a)				
	Nome	(a)				Mar 70	(a)				
	Point Barrow	(a)				Feb 70	(a)				
Ariz:	Phoenix	11	3	1	2	Aug 70	(a)				
Ark:	Little Rock	19	4	0	2	June 70	(a)				
Calif:	Berkeley	23	3	0	0	Sept 70	(a)				
	Los Angeles	23	3	0	1	Mar 70	(a)				
C.R:	Ancon	18	0	0	0	Sept 70	(a)				
Colo:	Denver	23	9	1	4	Sept 70	3	37	(d)		
Conn:	Hartford	23	2	1	1	Sept 70	4	19	4	19	6
Del:	Dover	22	2	0	1	July 70	(a)				
D.C:	Washington	23	1	0	0	May 70	(a)				
Fla:	Jacksonville	23	4	0	1	Feb 70	(a)				
	Miami	13	0	0	0	June 70	10	171	7	156	50
						July 70	7	73	5	54	0
Ga:	Atlanta	22	2	1	1	Apr 70	(a)				
Guam:	Agaña	(a)				May 70	(a)				
Hawaii:	Honolulu	27	1	0	0	Nov 70	2	11	(d)		
Idaho:	Boise	22	4	1	2	Nov 70	1	6	1	6	0
Ill:	Springfield	(a)				Feb 70	(a)				
	Indianapolis	16	7	0	2	Apr 70	(a)				
Iowa:	Iowa City	23	7	1	2	Sept 70	7	97	7	97	1
Kans:	Topeka	17	5	1	2	June 70	3	35	3	35	3
Ky:	Frankfort	21	1	0	1	Feb 70	(a)				
La:	New Orleans					Aug 70	9	138	(d)		
Maine:	Augusta	21	3	1	2	Mar 70	4	40	4	40	0
Md:	Baltimore	22	2	0	1	July 70	6	49	6	49	2
Mass:	Lawrence	22	2	0	1	Sept 70	4	56	4	56	6
Mich:	Windsor	21	3	0	1	Oct 70	3	37	3	37	0
Miss:	Lansing	30	3	0	1	Nov 70	11	86	11	86	10
Miss:	Minneapolis	23	3	0	2	May 70	8	139	8	139	25
Mo:	Jackson	19	2	0	1	Aug 70	4	114	4	114	9
	Jefferson City	22	5	1	2	Apr 70	3	34	3	33	1
Mont:	Helena	21	5	1	1	Oct 70	4	15	4	15	1
Neb:	Lincoln	16	8	0	3	Apr 70	3	100	3	100	45
Nev:	Las Vegas	22	2	1	2	July 70	(a)				
N.H.:	Concord	(a)				Feb 70	(a)				
N.J.:	Trenton	22	2	0	1	Aug 70	6	25	6	25	3
N. Mex:	Santa Fe	17	2	1	1	Oct 70	10	95	10	95	4
N.Y.:	Albany	11	2	0	1	Apr 70	5	48	5	48	22
	Buffalo	20	3	0	1	Sept 70	(a)				
	New York City	(a)				Oct 70	(a)				
N.C.:	Gastonia	17	7	1	3	Sept 70	4	48	(d)		
N. Dak:	Bismarck	23	5	1	2	Feb 70	5	46	5	46	7
Ohio:	Cincinnati	(a)				May 70	(a)				
	Columbus	(a)				Aug 70	(a)				
	Painesville	22	4	0	2	July 70	8	118	8	118	06
Okl:	Oklahoma City	22	4	1	2	Nov 70	1	11	1	11	2
Ore:	Portland	22	6	1	3	July 70	5	41	5	41	1
Pa:	Harrisburg	23	2	0	1	Apr 70	1	2	1	2	0
P.R.:	San Juan	13	1	0	1	Oct 70	1	19	1	19	4
R.I.:	Providence	(a)				Aug 70	(a)				
S.C.:	Columbia	23	2	0	1	Nov 70	2	10	2	10	1
S. Dak:	Pierre	19	5	0	1	Oct 70	4	130	2	90	3
		8	6	2	4	Aug 70	(a)				
Tenn:	Nashville	21	3	1	1	Nov 70	5	45	5	45	0
Tex:	Austin	21	11	2	5	May 70	1	5	(d)		
	El Paso	(a)				Feb 70	(a)				
Utah:	Salt Lake City	16	3	0	1	Mar 70	5	24	5	24	1
Vt:	Barre	16	5	0	2	June 70	6	52	6	52	7
Va:	Richmond	23	2	0	1	June 70	10	172	10	172	43
Wash:	Seattle	21	1	0	0	June 70	2	16	(d)		
	Spokane	21	2	1	1	May 70	(a)				
W. Va:	Charleston	23	2	0	1	Oct 70	10	128	10	128	19
Wisc:	Madison	23	3	1	1	June 70	6	64	6	64	10
Wyo:	Cheyenne	23	8	1	3	July 70	2	20	2	20	50
Network summary		1,183	11	0	2		218	72	5	63	13

- * The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
 * No report received. (Air samples received without field estimate data are not considered by the data program.)
 * No precipitation sample collected.
 * This station is part of the plutonium in precipitation network. No gross beta measurements are done.

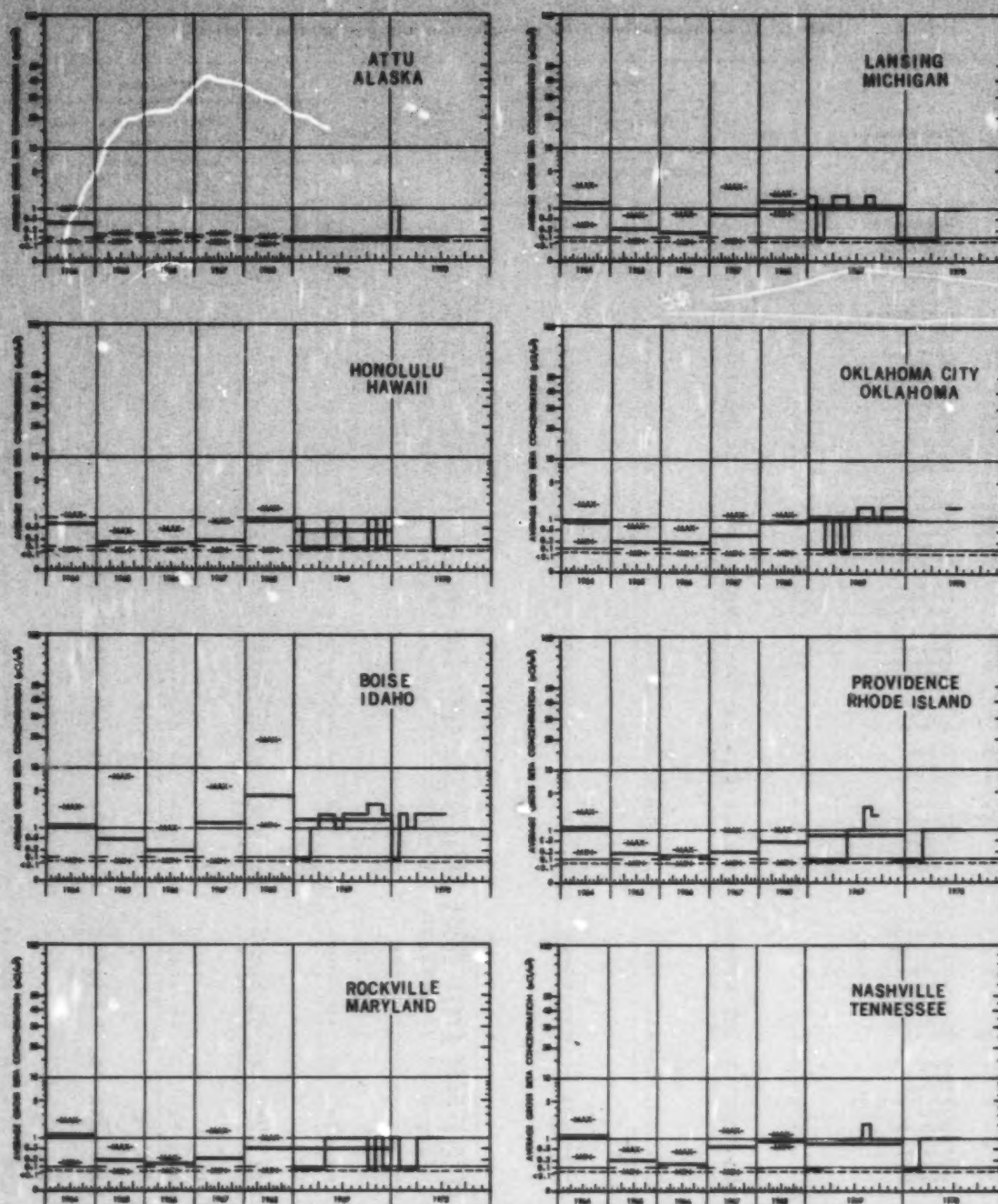


Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1964—July 1970

2. Canadian Air and Precipitation Monitoring Program,¹ July 1970

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (1-5).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports*.

¹ Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for July 1970 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, July 1970

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m ³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m ²)
Calgary	24	1.3	0.2	0.6	NB	NB
Coral Harbour	31	.3	.0	.1	83	4.3
Edmonton	31	.7	.1	.4	143	18.6
Ft. Churchill	31	.6	.1	.2	161	4.0
Fredericton	12	.6	.2	.3	48	8.4
Goose Bay	18	.9	.1	.3	NB	NB
Halifax	7	.3	.1	.2	67	5.3
Inuvik	6	.4	.1	.3	121	3.4
Montreal	31	.7	.2	.4	106	5.7
Moosee	6	.3	.0	.2	147	6.1
Ottawa	31	.6	.1	.4	46	4.3
Quebec	30	.6	.1	.4	111	13.3
Regina	6	.5	.1	.3	188	4.0
Resolute	11	.3	.0	.1	31	.5
St. John's, Nfld.	13	.4	.0	.3	87	2.0
Saskatoon	6	.5	.1	.3	265	8.3
Sault Ste. Marie	6	.5	.1	.3	106	11.4
Thunder Bay	31	1.1	.1	.4	139	12.7
Toronto	29	.7	.2	.4	25	3.1
Vancouver	3	.2	.1	.1	113	3.6
Whitehorse	31	.5	.0	.2	215	2.2
Windsor	31	.5	.1	.3	89	9.5
Winnipeg	NB				38	2.6
Yellowknife	31	.6	.1	.3	233	8.2
Network summary	456	1.3	0.0	0.3	116	6.4

NB, no sample



Figure 3. Canadian air and precipitation sampling stations

3. Mexican Air Monitoring Program July 1970

*National Commission of Nuclear Energy
México, D.F.*

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the División of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry

Department of the University of Mérida, the Instituto de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6 by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron daughters. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of five samples per month was needed to get a reliable average radioactivity at each station (6).

The maximum, minimum, and average beta radioactivity in surface air during July 1970 is presented in table 3.

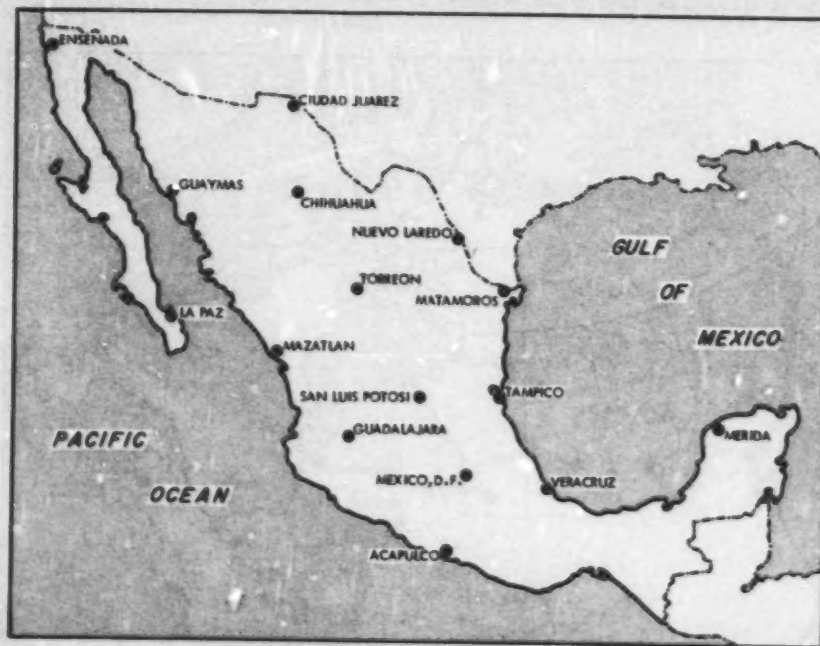


Figure 4. Mexican air sampling locations

Table 3. Mexican gross beta radioactivity of airborne particulates, July 1970

Station location	Number of samples	Gross beta radioactivity ($\mu\text{Ci}/\text{m}^3$)		
		Maximum	Minimum	Average
Aguascalientes	5	0.07	0.04	0.05
Chihuahua	15	.81	.18	.40
Ciudad Juarez	6	.68	.10	.29
Ensenada	NS			
Guadalajara	NS			
Guaymas	NS			
La Paz	NS			
Matamoros	NS			
Monterrey	NS			
Mérida	12	.60	.19	.35
México, D. F.	7	.24	.04	.09
Nevo Laredo	NS			
San Luis Potosí	NS			
Tampico	NS			
Torresón	16	.77	.24	.48
Veracruz	3			

NS, no sample, station temporarily shutdown.

4. Pan American Air Sampling Program July 1970

*Pan American Health Organization and
U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the January 1968 issue of *Radiological Health Data and Reports*. The July 1970 air monitoring results from the participating countries are given in table 4.

The higher levels of activity in La Paz, Bolivia; Guayaquil, Ecuador, and Lima, Peru, are attributed to the recent French nuclear tests in



Figure 5. Pan American Air Sampling Program stations

the Pacific. Gamma analyses of the filters indicate that the activity is due primarily to barium-lanthanum-140.

Table 4. Summary of gross beta radioactivity in Pan American surface air, July 1970

Station location	Number of samples	Gross beta radioactivity ($\mu\text{Ci}/\text{m}^3$)		
		Maximum	Minimum	Average*
Argentina: Buenos Aires	7	2.07	0.01	0.04
Bolivia: La Paz	20	10.25	.34	2.18
Chile: Santiago	30	2.02	.03	.67
Colombia: Bogota	23	.24	.01	.09
Ecuador: Cuenca	NS	NS	NS	NS
Guayaquil	20	14.06	.19	1.59
Quito	NS	NS	NS	NS
Guyana: Georgetown	10	.39	.07	.16
Jamaica: Kingston	NS	NS	NS	NS
Peru: Lima	25	23.82	.12	3.99
Venezuela: Caracas	18	.37	.02	.16
West Indies: Trinidad	NS	NS	NS	NS
Pan American summary	153	23.82	0.01	1.22

* The monthly average is calculated by weighting the individual sample with length of sampling period. Reported values of less than $0.005 \mu\text{Ci}/\text{m}^3$ are considered as $0.00 \mu\text{Ci}/\text{m}^3$ in averaging.
NS, no sample.

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- (6) VASQUEZ, M. and R. M. DE NULMAN. Estudios sobre la radioactividad ambiental en la Republica Mexicana, 1963-1965. Comisión Nacional de Energía Nuclear, Dirección General de Seguridad Radiológica (1966).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included

here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety

in directives published in the "AEC Manual."¹

Summaries of the environmental radioactivity data follow for Lawrence Radiation Laboratory and Shippingport Atomic Power Station.

¹ Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Lawrence Radiation Laboratory July-December 1969²

*University of California
Berkeley, Calif.*

Berkeley site

The Berkeley site of the Lawrence Radiation Laboratory (LRL) is situated on the western slope of the range of hills running along the eastern side of San Francisco Bay. The laboratory area is largely separate from the main campus of the University, although there is some overlap (figure 1).

To the north and south of the laboratory area are residential areas of the cities of Berkeley and

² Summarized from "Results of Environmental Radioactivity Sampling Program, July-December 1969," Lawrence Radiation Laboratory, Livermore and Berkeley, Calif.

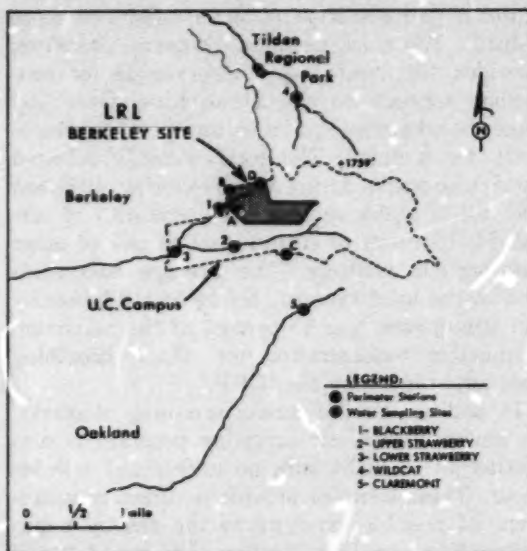


Figure 1. Environmental sampling locations at the Berkeley Site, Lawrence Radiation Laboratory

Oakland. The Berkeley campus of the University of California is on the west; to the east are the Lawrence Hall of Science and the Space Sciences Laboratory; beyond them lies uninhabited watershed land and the Tilden Regional Park.

The most prevalent wind direction is westerly. During the summer months the afternoon sea breeze establishes a very pronounced prevailing westerly wind direction. At other times, the direction is less predictable. Annual rainfall is 23 inches, almost all of which falls between November 1 and May 1. The prevailing wind direction during precipitation is southerly.

The laboratory carries on a wide ranging program of general research in the fields of both physical and biological sciences. Facilities include a number of large accelerators and various physics, chemistry, biology and medical research laboratories.

The basic policy at LRL has long been to prevent, as far as possible, any release of radioactive material to the environment, no matter how small. No deliberate releases are sanctioned, except where no practical method for containment has yet been developed and quantities are small compared with standards established by the ICRP and AEC.

The most sensitive measurements of releases are those taken closest to the source itself, before dilution makes detection of small quantities more difficult. The stack sampling program, therefore, provides the most useful information for controlling releases to the atmosphere. Over 100 separate exhausts from hoods and glove-box manifolds are sampled. The total quantity released from these stacks during July-December 1969 was 130 nCi of alpha radioactivity, 360 mCi of carbon-14, 19 curies of tritium and 65 μ Ci of other beta-particle emitters. The average concentration in the total exhaust, before any dilution by the atmosphere, was 15 percent of the maximum permissible concentration for offsite breathing zone air, as given by the ICRP.

In addition to the careful sampling of stacks, an environmental air sampling program is also carried on to make sure no undetected releases occur. These samples provide a direct measurement of possible exposure to the nearby population. The sampling stations designated "local area" are scattered around the site and provide samples of the atmosphere on the site itself. The

"perimeter" samples are taken at the boundary line of University property, in the direction of populated areas. From the results of these samples, it is apparent that there has been no significant exposure from radioactive materials released by LRL. The levels of radioactivity observed in each type of sample are presented in table 1.

Table 1. Atmospheric monitoring, LRL Berkeley site July-December 1969

Sampling locations (number of locations)	Number of samples	Average concentration (pCi/m ³)			
		Alpha radioactivity		Beta radioactivity	
		Average	Maximum	Average	Maximum
Local area (10).....	263	0.000	0.006	0.20	0.65
Perimeter (4).....	105	.001	.006	.20	.95

Rain or dry fallout is also collected at each of these environmental stations. Open 15-inch diameter polyethylene bags form the collecting vessel. If no rain has fallen, the bags are rinsed out with dilute nitric acid to obtain a sample. Since on the average, the more remote perimeter stations show about the same radioactivity as the nearer ones, the radioactivity does not result from laboratory operations. The radioactivity levels in samples collected at each location are summarized in table 2.

Table 2. Total deposition, LRL Berkeley site July-December 1969

Sampling locations (number of locations)	Number of samples	Average deposition (nCi/m ²)			
		Alpha radioactivity		Beta radioactivity	
		Average	Maximum	Average	Maximum
Local area (10).....	51	0.03	0.11	3.19	4.36
Perimeter (4).....	22	.07	.10	3.03	4.54

All liquid waste known to be radioactive is collected, solidified, and shipped away. Other liquid wastes are discharged directly to the municipal sewer system. Small quantities of radioisotopes now and then are accidentally released to the sewer system. There are two outfalls, each of which is monitored by a continuous proportional sampling system to insure that no significant quantities have been discharged. The total concentration (alpha-plus-beta radioactivity) in sewage is only 15 percent of the standard for drinking

water and therefore does not constitute an exposure threat. A sizeable fraction of the measured beta concentration is the naturally occurring isotope potassium-40 from human wastes and chemicals.

The storm drainage from the laboratory flows into the surface stream system. These surface streams are exposed as they run through the University property and are sampled at three places. Results are listed as "onsite streams" in table 3. Two nearby offsite streams are also sampled to provide a comparison. All concentrations are safely below the standard for drinking water. The results from the water sampling program are presented in table 3.

Table 3. Water monitoring, LRL Berkeley site July-December 1969

Type and source of sample	Number of samples	Concentration (pCi/liter)			
		Alpha radioactivity		Beta radioactivity	
		Average	Maximum	Average	Maximum
Surface water:					
Onsite streams:					
Blackberry-----	27	0.23	1.3	3.84	21.5
Lower Strawberry-----	27	.90	3.1	11.71	54.6
Upper Strawberry-----	27	.44	3.6	4.31	15.8
Summary-----	81	.52		6.62	
Offsite streams:					
Claremont-----	27	.58	6.6	3.12	19.1
Wildcat-----	27	.38	2.2	3.28	9.1
Summary-----	54	.46		3.28	
Tap water-----	51	.023	.18	1.20	2.3

Neutron and gamma-ray fields are measured at each of the four perimeter stations as well as at several locations within the site. Background measurements are obtained from a leased building used as a low-level counting room in downtown Berkeley. This building is remote from the main LRL site and measurements are not influenced by accelerator operations.

At each station, gamma measurements are made by a recording G-M detector, standardized with a calibrated radium source. These instruments operate unattended, and each can operate for 1 week on its internal battery, should external power fail.

Several neutron detectors are employed at each station. The primary detector is a BF₃ gas proportional counter in a 2 1/2 inch-thick paraffin-lined moderator. This detector is sensitive in the region from 0.1 to 20 MeV, where 75 percent of the biologically significant neutrons exist. A polyethylene-lined proton recoil neutron detector provides a measure of the energy flux density. The ratio of energy flux density to neutron flux density gives the average neutron energy which allows conversion of the data to dose in rems. Cobalt disks in moderators are maintained as long term integrating neutron monitors at many sites throughout the laboratory as well as at each perimeter station.

Cosmic ray intensity is continuously monitored by a meson detector with an effective angle of acceptance of 2.3 steradians (in the upward direction). This provides information on the background neutron levels contributed by cosmic rays.

At each station, total radiation levels are well below the standards set for the general public by the ICRP and NCRP. Levels are somewhat higher than they were during the first 6 months of 1969. Results are presented in table 4.

Livermore site

The Livermore site of LRL (figure 2) is located in the Livermore Valley midway between the Pacific coast and the San Joaquin Valley in northern California, approximately 50 miles southeast of San Francisco. Shielded from the ocean

Table 4. Beta-gamma and fast neutron surveillance results, Berkeley site, January-December 1969

Station	Total beta-gamma exposure (mrem) (background subtracted)		Total fast neutron exposure (mrem) (background subtracted)	
	January-June 1969	July-December 1969	January-June 1969	July-December 1969
A-----	10.9	14.3	38.89	226.6
B-----	4.4	8.7	26.42	77.3
C-----	(a)	(a)	(a)	.31
D-----	6.1	5.1	55.67	39.9
Shattuck Ave. and Berkeley Way-----	(a)	(a)	(a)	(a)

^a 2.45×10^7 n/cm² = 1 rem.

^b Background.

^c Detector not in service.

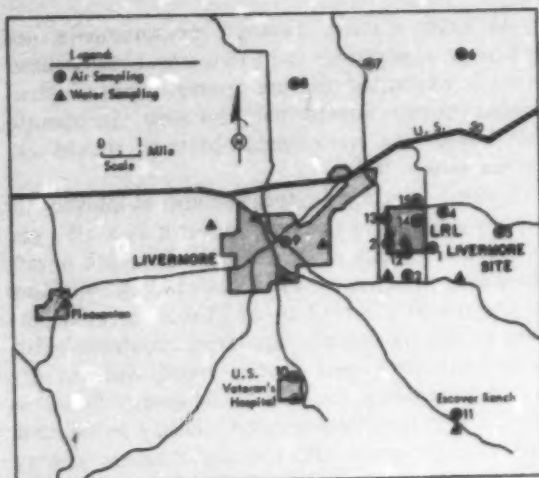


Figure 2. Environmental sampling locations at the Livermore Site, LRL.

by the western hills, the Livermore Valley has a warm, dry climate. Annual rainfall is about 14 inches and the relative humidity is about 30 percent during the summer months and about 40-50 percent the remainder of the year. Prevailing winds are from the west, but inversions are frequent during the night.

Agriculture is the principal activity in the Livermore Valley. Roses, grain, hay, and grapes are the major products. Several cattle and sheep ranches surround the Livermore site.

The Livermore site comprises an area of 1-square mile, approximately 3 miles east of the city of Livermore. Livermore and Pleasanton, with a combined population of 45,000, are populated areas of primary interest to the Livermore site.

An environmental sampling program is maintained to provide information regarding the effectiveness of control measures and to determine whether any radiological changes in the environment are the result of laboratory operations. The sampling program includes air particulates, soil, domestic water, sewer effluent, sewage plant products, milk, and vegetation. The milk samples are obtained from one dairy in the Livermore Valley and from another dairy near Site 300. Air and soil samples are collected to ascertain that control efforts are restricting the release of radioactivity from the laboratory to levels which do not exceed the permissible levels for the neighborhood around an atomic energy facility. The water

samples are collected to ascertain that radioactivity is not entering the underground water supply which provides most of the domestic water for the cities of Livermore and Pleasanton and is the sole supply for ranches in the Livermore and Amador Valleys. Samples were taken at the Livermore Sewage Disposal Plant to establish that liquid effluent from the laboratory is not contributing significant radioactivity to the dried sludge or liquid effluent produced. The dried sludge is used as an agricultural soil conditioner. Some liquid effluent released to the Los Positas Arroyo is used for irrigation of the golf course turf and some agricultural land.

Air samples are collected continuously at 15 sites within 5 miles of the laboratory. Samples are collected at a rate of 4 cfm on 100 cm² HV-70 filter papers, which are changed after every 7 days of operation. A minimum decay period of 96 hours is observed before the samples are counted to eliminate the effect of natural radon and thoron daughters. At no time was any detectable alpha radioactivity observed on the air filters. The average airborne beta radioactivity of 0.1 pCi/m³ was about the same as that reported during the previous 6 months. The beta radioactivities were below the AEC radiation protection standard of 1 pCi/m³.

The measurement of low level "background" radiation during this period was accomplished with thermoluminescent dosimeters located at nine points on the site perimeter and at three off-site locations. The exposures are reported as the difference between the TLD reading and normal background for this area. Differences of 10 mR or less are not considered significant and are reported as <10 mR. The three offsite locations recorded no exposures attributable to Livermore operations. At three of the nine locations in the controlled area, exposures of 17 to 29 mR were recorded (table 5).

Domestic water samples were collected monthly from ten nearby sources. No sample showed an alpha specific radioactivity above the limit of detection (5.0 pCi/liter). The beta radioactivity fluctuated from the limit of detection (1.8 pCi/liter) to 10 pCi/liter. The average beta radioactivity concentration was 2.2 pCi/liter. The average alpha and beta radioactivity concentrations were below the AEC standard of comparison of 30 pCi/liter.

Table 5. External gamma radiation measurements, LRL Livermore site, July-December 1969

Dosimeter location ^a	Exposure ^b (mR)
1	<10
2	<10
3	<10
4	29
5	<10
6	26
7	<10
8	17
9	<10
10	<10
11	<10
12	<10

^a Locations 1-3—uncontrolled area.

Locations 4-12—controlled area perimeter.

^b The figures in this column are the difference between the TLD badge and normal background. Exposure differences of 10 mR or less are reported as <10 mR.

The tritium radioactivity of water samples ranged from the limit of detection (5 nCi/liter) to a high value of 5.5 nCi/liter.

Samples were collected daily at the laboratory sewer discharge. The average alpha radioactivity concentration in the sewer effluent ranged between 9 and 38 pCi/liter while the monthly average beta radioactivity varied between 170 and 780 pCi/liter. The AEC standard is 400 pCi/liter. The average tritium content of the effluent was 77 nCi/liter with a maximum of 5,700 nCi/liter. The AEC standard is 100 mCi/liter. The effluent was analyzed for strontium-90 and radium-226-228 radioactivities. The average monthly radioactivity of strontium-90 ranged from 5.7-20 pCi/liter; radium-226-228 ranged from 2.5 to 7.6 pCi/liter.

Samples of top layer soil are collected quarterly at the 19 sampling stations surrounding the Livermore site. The alpha radioactivity of each sample was less than the limit of detection (1.5

pCi/g). The beta radioactivity fluctuated from the limit of detection (3.5 pCi/g) to 17.2 pCi/g, averaging 6.6 pCi/g. The concentrations detected are within the normal range for soil in the Livermore Valley, as determined from surveillance during previous years.

Average radioactivity levels in monthly milk samples amounted to 1.7 pCi/liter of cesium-137 and 3.6 pCi/liter of cerium-141-144, for the two dairies. The average tritium concentration in milk was at or below the limit of detection (5 nCi/liter). Vegetation samples were collected during September and December of 1969. The radioactivity of 15 unwashed grass sampler and four eucalyptus leaves samples is presented in table 6. A portion of each sample was freeze dried, and the water collected was analyzed for HTO.

Continuous radioactive air sampling is maintained on the effluent from stacks of operations that are potential sources of radioactive material releases. These facilities include the hot cells, transuranic chemistry, plutonium metallurgy, critical assembly cells, and the reactor building.

The effluent from these buildings passes through absolute filters prior to being exhausted to the atmosphere. The limit of sensitivity for the stack monitoring systems is generally 0.1 pCi/m³ or less. The permissible offsite concentrations were not exceeded as a result of stack effluent during the past 6 months.

Site 300

The high-explosive test area at Site 300 (figure 3) covers 10-square miles in the hills in a very sparsely populated ranching area about 15 miles southeast of Livermore and 8 miles southwest of

Table 6. Radioactivity in vegetation, LRL Livermore site July-December 1969

Nuclide	Concentration (pCi/g dry weight)*				Limit of detection
	Grass		Eucalyptus leaves		
	Average	Maximum	Average	Maximum	
Beryllium-7	0.73	2.40	0.07	0.24	0.01
Manganese-54	.03	.05	.01	.02	.01
Zirconium-95	.36	.66	.13	.23	.01
Ruthenium-106, 106	.23	1.02	.17	.18	.02
Antimony-125	.09	.07	.02	.05	.02
Cesium-137	.01	.11	.01	.01	.01
Cerium-141, 144	1.05	2.23	.28	.51	.02
Tritium	23	130	10	25	5

^a Except tritium which is nCi/liter of water.

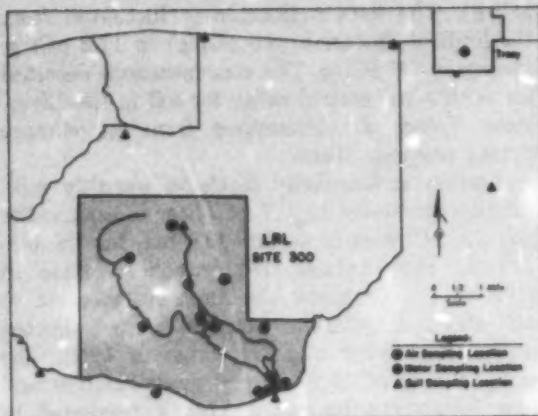


Figure 3. Sampling locations at Site 300, LRL

Tracy. The chief area of concern for Site 300 is Tracy. The population there is about 15,000. Air and water samples are taken to determine whether operations at Site 300 are changing the normal radioactivity levels in the vicinity. The 10 air samplers at Site 300 are operated at about 50 cfm on a continuous basis with the filter papers being changed on regular schedule. Most of these air samplers are located within the boundaries of the test site due to unavailability of electric power facilities offsite (table 7). Water samples are taken from onsite wells because they are the only readily accessible sources of underground

water. Streams in the area are sampled when they contain water. No sample showed an alpha radioactivity concentration above the limit of detection (5.0 pCi/liter). The beta concentration ranged from the limit of detection (1.8 pCi/liter) to 12 pCi/liter, averaging 4.5 pCi/liter. The average tritium concentration was at or below the detectable level of 5 nCi/liter.

Soil samples are collected quarterly at nine offsite locations. The alpha radioactivity of each sample was 1.5 pCi/g, the limit of detection. The beta radioactivity ranged from the limit of detection (3.5 pCi/g) to 17 pCi/g, with an average activity of 9.2 pCi/g.

None of the average concentrations of air, water, and soil samples exceeded the standards of comparison applicable to activities at the test site, nor did any of the results increase significantly compared to 1968 data. Therefore, it appears that radiological control measures at Site 300 were adequate and that no significant radioactivity was released to the environment near the site during this period.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January–December 1968	October 1969
January–June 1969	April 1970

Table 7. Airborne particulate radioactivity, LRL Site 300 July–December 1969

Sampling location	Number of samples	Alpha radioactivity* (fCi/m ³)		Beta radioactivity* (fCi/m ³)	
		Average	Maximum	Average	Maximum
1	38	<0.2	<0.2	132	480
2	39	<.2	1.2	165	830
3	36	<.2	<.2	205	1,060
4	37	<.2	<.2	151	483
5	39	<.2	<.2	146	384
6	30	<.2	1.0	124	499
7	38	<1.0	<1.0	187	472
8	34	<.2	<.2	156	613
9	34	<.2	<.2	156	413
10	36	<.2	<.2	160	419
Summary				150	

* Limit of detection—Alpha radioactivity—location 1–6, 0.2 fCi/m³, location 7, 1.0 fCi/m³.

Beta radioactivity—location 1–6, 0.2 fCi/m³, location 7, 1.0 fCi/m³.

Variations in limits of detection result from differing flow rates. Estimated error limits—alpha radioactivity, ± 30 percent; beta radioactivity, ± 30 percent.

2. Shippingport Atomic Power Station January-December 1969^a

*Duquesne Light Company
Shippingport, Pa.*

The Shippingport Atomic Power Station is located on the south bank of the Ohio River in a site consisting of over 400 acres. The site is about 25 miles northwest of Pittsburgh and about 11 miles below the confluence of the Beaver and Ohio Rivers (figure 4). The station is designed to produce electric energy by a conventional central station type turbine-generator unit. The pressurized water reactor consists of a closed system in which water is circulated by pumps over an array of nuclear fuel elements, or core, contained in a reactor vessel, to heat exchangers where steam is formed in a separate isolated system.

Radioactive waste handled under the environmental program includes liquid and gaseous effluents released into the Ohio River and atmosphere, respectively. The levels of radioactivity released were below Shippingport discharge limits.

^a Summarized from "Environmental Radioactivity at the Shippingport Atomic Power Station for the Calendar Year 1969."

These limits are based upon radiation standards set forth by AEC's division of Operational Safety in directives published in the AEC Manual¹ and a waste discharge permit from the Pennsylvania Sanitary Water Board.

Ohio River water analysis

During 1969, weekly composite samples were obtained from two continuous automatic samplers in the station circulating water line upstream and downstream from the radioactive water effluent. Both suspended and dissolved materials in the composite samples were analyzed for gross alpha and beta radioactivity. Each composite is also analyzed for potassium-40 content. No significant difference was observed among the average alpha, beta, and potassium-40 radioactivity for the influent samples. The results of these analyses are presented in table 8.

Ohio River sediment analysis

Once during each calendar quarter, sediment samples from the Ohio River were collected upstream and downstream from the circulating water outfall with a Birge-Ekman dredge. These samples were quantitated assuming all detected radioactivity to be cobalt-60, which is the major constituent of radioactive contamination at the sta-



Figure 4. Shippingport Power Station sampling locations

Table 8. Gross radioactivity in the Ohio River, Shippingport Atomic Power Station, January-December 1969

Type of radioactive material	Average concentration (pCi/liter)							
	Influent samples				Effluent samples			
	Jan-March	April-June	July-Sept	Oct-Dec	Jan-March	April-June	July-Sept	Oct-Dec
Alpha:								
Total solids.....	0.61	0.67	1.17	1.90	0.60	0.70	1.23	1.47
Beta:								
Total solids.....	8.90	12.00	15.00	14.90	9.00	14.00	12.80	15.40
Potassium-40.....	3.2	4.2	6.0	8.8	3.1	4.3	6.1	8.8

tion. The results of the sediment samples are presented in table 9. These data indicate that there was no increase of radioactivity in the river sediment as a result of the station's discharges.

Table 9. Total radioactivity in the Ohio River sediment samples, Shippingport, January-December 1969

1969	Number of samples	Gross radioactivity (pCi/g)	
		Upstream	Downstream
January-March.....	2	7.50	8.00
April-June.....	2	9.10	7.80
July-September.....	2	8.49	7.67
October-December.....	2	9.35	9.81

Liquid radioactive waste

The liquid radioactive wastes disposed of at Shippingport are primarily from the reactor coolant system. The radioactive waste produced by the plant is reduced in concentration in such a manner that the concentration of these wastes in water measured at the condenser water stream before discharge to the Ohio River meets the limits as delineated above. In order to assure that the liquid discharged from the plant will meet specified tolerances, all radioactive waste is collected, processed, and sampled prior to discharge to the environment.

During 1969, a total of 208 mCi gross beta-gamma radioactivity in the liquid waste (exclusive of tritium) and 20 Ci of tritium in liquid waste were released into the environment. The average daily discharge of tritium during this period was 55 mCi. All reported concentrations released to the environment were well below those specified by State and Federal regulations.

Gaseous radioactive waste

Gaseous discharges to the atmosphere, identified as xenon-133, are controlled and released at concentrations less than the AEC standard of 300 nCi/m³. During the year 1969, a total of 75.0 microcuries of xenon-133 were released from the plant site at less than the specified concentration.

Film badge monitoring

Twelve film badges for detecting beta-gamma radioactivity were posted continuously at the site perimeter in an attempt to determine the external radiation exposure in the immediate area. In order to accomplish this, a control film badge location was established at a point 10 miles from the station boundary.

The construction of the Beaver Valley Nuclear Unit necessitated the permanent change in the location of four of the environmental monitoring film stations. The frequency of film change and development has been changed from a quarterly to a monthly basis.

Since the minimum detectable exposure of the type of film used is 25 mrem, all film which indicate less than this are reported as "0" mrem. In all cases, the film density was not measurably different from the control film. This indicates that the film exposure at all locations averaged 0.03 mrem/h for each month of 1969 which is considered normal background radiation for this area. These results show that radiation exposure to the general public outside the station was not above that received from natural background radiation levels.

Fallout

Precipitation and fallout are collected in high-walled pot at one location on the site and analyzed monthly for gross alpha and beta radioactivity. A summary of the quarterly average fallout results for 1969 is presented in table 10.

Table 10. Radioactivity in fallout, Shippingport January-December 1969

1969	Deposition rate (mCi/m ² /month)	
	Alpha radioactivity	Beta radioactivity
January-March.....	0.13	3.94
April-June.....	.20	13.56
July-September.....	.27	4.00
October-December.....	.18	17.40
Yearly average.....	0.20	9.52

Conclusion

From the data presented above, it may be concluded that, during 1969, the radioactive effluent releases from the Shippingport station site did not cause any significant increase in background radiation levels. In this regard, the station procedures relative to controlling radioactive discharges to the environment are considered to be effective in protecting the health and safety of the general public.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January-December 1968	October 1969

Reported Nuclear Detonations, October 1970

(Includes seismic signals from foreign test areas)

The U.S. Atomic Energy Commission (AEC) announced only one United States nuclear test for October 1970. A nuclear test in the yield range between 20 and 200 kilotons TNT equivalent was conducted underground on October 14, 1970, by the AEC at its Nevada Test Site.

On October 14, 1970 the United States recorded seismic signals, presumably from a Soviet underground nuclear explosion. The signals originated at approximately 0200 e.d.t., at the Novaya

Zemlya nuclear test area and were equivalent to those of an underground nuclear explosion with a yield of about 6 megatons. This is the largest such event detected in this area.

The AEC also announced that Communist China set off a nuclear explosion in the atmosphere at approximately 0330 e.d.t., October 14, 1970, at their Lop Nor nuclear test area. The yield was about 3 megatons. This is the first Chinese test announced this year.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U. S. nuclear detonations may be obtained upon request from the Division of Public Information, U. S. Atomic Energy Commission, Washington, D. C. 20545.

SYNOPSIS

Synopsis of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

ANALYSIS OF IODINE-131 DATA IN BOVINE THYROIDS FOR OCTOBER 1964 THROUGH FEBRUARY 1969. John L. Russell and Gerald A. Pliner. *Radiological Health Data and Reports*, Vol. 11, November 1970, pp. 573-580.

A detailed analysis of the bovine thyroid data from October 1964 through February 1969, as reported in *RHD&R*, shows that most positive results can be related to various nuclear tests with known atmospheric intrusions. The widespread nature of various samples having positive concentrations of short-lived fission products and the rapid increase of levels in these samples indicate the source to be a major atmospheric intrusion.

Estimates determining thyroid dose in man from iodine-131 concentrations in bovine thyroids appear to be feasible under selected conditions but are of little use in evaluating nationwide network data. The lower limit of detectability is 1 pCi ¹³¹I/g bovine thyroid, and most samples at this level have a 2-standard deviation error greater than the measured quantity.

KEYWORDS: Atmospheric intrusions, iodine-131, bovine thyroid, summary, United States.

RESULTS OF 33,911 X-RAY PROTECTION SURVEYS OF FACILITIES WITH MEDICAL OR DENTAL DIAGNOSTIC X-RAY EQUIPMENT, FISCAL YEARS 1961-1968. Lawrence R. Fess, Richard B. McDowell, Wayne R. Jameson and Ray W. Alcox. *Radiological Health Data and Reports*, Vol. 11, November 1970, pp. 581-612.

The results of radiation surveys of 33,911 medical and dental x-ray facilities are presented and analyzed. It was found that a high percentage of x-ray machines in medical facilities have improper collimation and inadequate filtration. In addition, a large proportion of the facilities do not possess adequate accessory patient or operator shielding. The use of an open-end aiming device high-speed film, and the need to improve darkroom procedures were the primary recommendations made for dental facilities.

KEYWORDS: Collimation, dental x-ray facilities, diagnostic x-ray equipment, filtration, fluoroscopic machines, healing arts, x-ray medical facilities, radiographic machines, radiation surveys, United States, x ray.

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 11, Number 12, December 1970

In August 1969, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and x rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Bureau of Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

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CONTENTS

Page

REPORTS

Radioactive Cesium in Estuaries..... 659
Gordon K. Riel

Nassau County Microwave Oven Study, June 1969-March
1970..... 667

*David Mafriqi, Sheldon V. Bernstein, and
Charles E. Miller*

Krypton-85 Levels in the Environment Determined from
Dated Krypton Gas Samples..... 671

R. E. Shuping, C. R. Phillips, and A. A. Moghissi

DATA

SECTION I. MILK AND FOOD..... 673

Milk Surveillance, August 1970..... 673

Food and Diet Surveillance..... 684

1. Estimated Daily Intake of Radionuclides in Connecticut
Standard Diet, July-December 1969..... 684

SECTION II. WATER..... 687

Interstate Carrier Drinking Water Analysis Program 1967-
1969, *PHS*..... 688

Tritium in Community Water Supplies, 1969, *PHS*..... 692

CONTENTS—continued

	Page
SECTION III. AIR AND DEPOSITION	696
Radioactivity in Airborne Particulates and Precipitation.....	696
1. Radiation Alert Network, August 1970, <i>PHS</i>	696
2. Canadian Air and Precipitation Monitoring Program, August 1970.....	699
3. Pan American Air Sampling Program, August 1970, <i>PAHO</i> and <i>PHS</i>	700
SECTION IV. OTHER DATA	701
Environmental Levels of Radioactivity at Atomic Energy Commission Installations.....	701
1. Mound Laboratory, July–December 1969.....	701
2. Savannah River Plant, July–December 1969.....	704
3. S1C Prototype Reactor Facility, January–December 1969.....	711
Reported Nuclear Detonations, November 1970.....	713
Nuclear Power Plants in the United States.....	714
ANNUAL SUBJECT INDEX, VOLUME 11	717
ANNUAL AUTHOR INDEX	723
Synopses.....	iii
Notice to Subscribers.....	back
Guide for Authors.....	Inside back cover

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Radioactive Cesium in Estuaries

Gordon K. Riel¹

The concentration of dissolved cesium-137 from fallout in the Chesapeake Bay is on the order of 0.3 pCi/liter, while the concentration is less than 0.1 pCi/liter in the rivers and ocean that supply the Bay's water. The ratio of radiocesium concentration to salinity in the Bay is fairly independent of location and season. Brief studies elsewhere indicate that this pattern is typical of estuaries.

The Chesapeake Bay has been described as "the most valuable . . . and the most threatened estuary in the world" (1). Its drainage area extends into six States, and it receives agricultural, industrial, and domestic wastes from 12 million people. Knowledge of the behavior of cesium in bodies of water and drainage systems will help determine mass transfer coefficients which are needed for various types of pollution control, as well as for the control of releases from nuclear reactors planned for the bay and its tributaries. This report presents the results of studies of cesium-137 concentrations in Chesapeake Bay, in surface waters draining into it, and in nearby coastal Atlantic Ocean waters.

Table 1 presents information about the dimensions of the bay. The net water transport which flushes the bay is only about 10 percent of the tidal flow. Therefore, the residence time of water in the bay is calculated to be about a year, by dividing the total volume (75×10^9 cubic meters) by the net flow rate (2×10^9 cubic meters per second).

Method

Cesium is extracted by pumping water through the inorganic exchanger, potassium hexacyanocobalt (II) ferrate (II) (KCFC) (2, 3). A dip filter keeps solids out of the exchanger, and a flowmeter measures the volume of water pumped.

¹ Dr. Riel is a research physicist in the Nuclear Physics Division of the U.S. Naval Ordnance Laboratory (NOL), Silver Spring, Md. 20910.

Table 1. Chesapeake Bay: selected data (1)
(values are approximate)

Length.....	195 miles	
Width.....	3.4 to 35 miles	
Surface area of water:		
Bay.....	2,320 square miles	
Tributaries.....	2,120 square miles	
Mean depth:		
Bay.....	27.7 feet	
Bay and tributaries.....	21.4 feet	
Drainage area:		
Piedmont.....	50,000 square miles	
Coastal plain.....	14,900 square miles	
Total.....	64,900 square miles	
Number of tributaries: rivers, creeks, branches.....	150	
Navigable distance, tidewater.....	1,750 miles	
Shoreline length, bay and tidewater tributaries.....	4,600 miles	
Average stream discharge (4), cubic feet per second:	1968	1969
Susquehanna River.....	32,200	28,100
All rivers.....	60,100	54,900
Sediment discharge (5):		
Susquehanna River.....	0.95×10^6 tons/a	
Potomac River.....	1.4×10^6 tons/a	
Cesium-137 fallout per year (6):		
Per square meter.....	2 nCi	
Total.....	30 Ci	

One hundred grams of KCFC will extract 70 percent of the dissolved cesium from 600 liters of water per hour. The cesium-137 content of the KCFC is determined by gamma spectrometry, with an error (counting and systematic) of ± 20 pCi. Therefore, an accuracy of ± 0.02 pCi/liter requires a total flow of 1,400 liters or about $2\frac{1}{2}$ hours pumping.

Duplicate determinations were made both with other laboratories and by analyzing the same KCFC sample repeatedly at NOL. Five out of seven samples counted by the Bureau of Commercial Fisheries Radiobiology Laboratory, Beaufort, N.C. (RBL) and 15 out of 30 samples counted by the Maryland Department of Health, Bureau of Laboratories, Baltimore, Md., agreed with our analysis within the stated error.

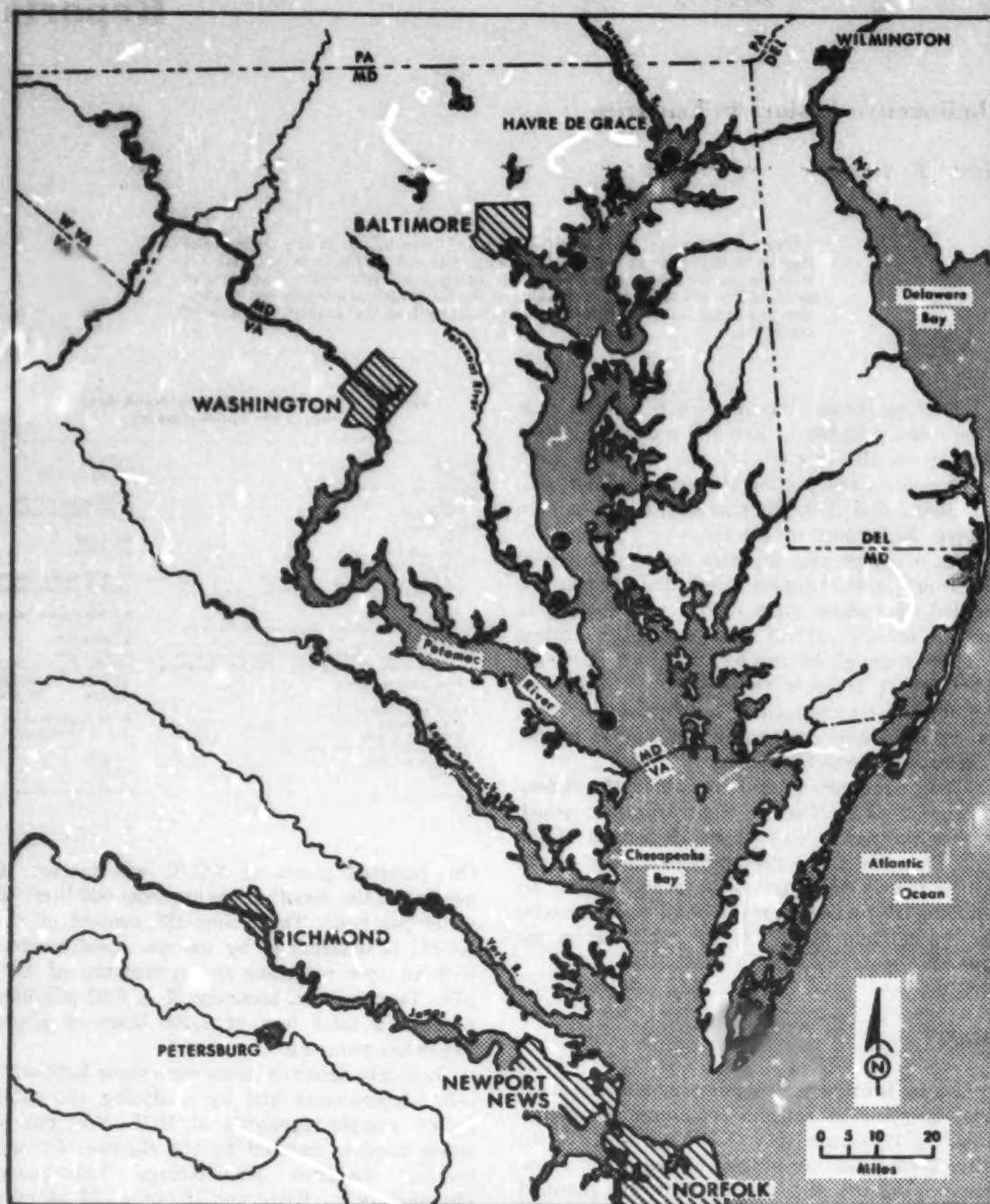


Figure 1. Chesapeake Bay sites of cesium-137 measurements

Extraction efficiency is checked frequently by pumping the water through two beds of KCFC in series. At three sites, the effluent water was acidified to ionize any cesium complexes and reanalyzed. None were found. Errors in extraction efficiency, water volume, and cesium-137 standard sources give a proportional error of about ± 20 percent.

Tests at shallow water sites near shore are influenced by rainfall and evaporation. However, by normalizing for salinity, values typical of offshore water are obtained. These are reported as cesium-137 to potassium ratios assuming that the potassium concentration is a constant fraction of salinity.

Results

Six sites, each with a pier in water 1 to 2 meters deep (figure 1 and table 2), along the western shore of the Chesapeake Bay were tested periodically from June 1968 through January 1970. Tests along the bay's ship channel (figure 2 and table 3) verified that the shore sites received typical surface water. Deep water at the bottom of the channel had only about half the concentration of cesium that surface water had. However the deep channel is narrow so most of the water is like surface water. The ratio of radiocesium to salinity is fairly constant so the bay's cesium-137 content may be estimated from the salinity distribution.

The Patuxent River (table 4) has a cesium-137 distribution similar to that of the bay; that is, the ratio of cesium-137 to salinity is about 0.002 in the surface water and about 0.001 near the bottom. At Chalk Point, where a significant portion of the river is circulated through the power plant, these ratios are reversed.

A dozen clams (*Mya arenaria*) were collected by personnel of the Chesapeake Biology Laboratory at each of these sites (table 4) during the Patuxent River test, but the cesium-137 content was undetectable. Therefore, in February 1969, they collected a bushel of clams from water with a salinity of 13.3 ‰ (parts per thousand) and a cesium-137 concentration of 0.1 pCi/liter. Cesium-137 amounting to about 3 percent of the natural potassium-40 radioactivity, was detected in this large sample (table 4).

Repeated measurements in fresh water (table 5) have convinced us that little dissolved cesium-137 enters the bay that way. The concentration in fresh water does not average more than 0.01 pCi/liter, so a year's flow at $2.8 \times 10^3 \text{ m}^3/\text{s}$ (10^5 c.f.s.) will deliver less than 1 curie of cesium-137. Mud contained less than 50 pCi cesium-137/kg wet weight so a typical discharge into the bay of 10^4 tons per year (5) would deliver less than 0.05 curies annually. These are small compared with the direct fallout deposition of about 20 curies per year.

Table 2. Cesium-137 in the Chesapeake Bay near the western shore

Site ^a	Adjacent river	Date	Salinity ‰	Cesium-137 concentration	
				(pCi/liter) ^b	(pCi/g K) ^c
Spessie Island:.....	Susquehanna	7/18/68	—	0.05 ± 0.02	—
		9/11/68	1.4	.07 ± .02	4.4 ± 1.3
		10/2/68	2.2	.03 ± .02	1.1 ± .5
Causeway, south side.....		11/1/68	4.1	.14 ± .04	3.0 ± .9
Causeway, north side.....		11/1/68	4.0	.07 ± .02	1.6 ± .4
Causeway, north side.....	Rack	6/3/69	.4	.03 ± .02	0 ± 2
Causeway, north side.....		10/1/69	.6	.05 ± .02	9 ± 2
Swans Point, Baltimore.....		5/27/69	3.0	.06 ± .02	1.7 ± .4
		9/5/69	6.1	.27 ± .02	3.6 ± .3
		9/12/69	13.7	.22 ± .02	1.4 ± .1
Bay Bridge:.....		10/17/68	13.0	.12 ± .05	.8 ± .3
		1/28/69	6.8	.09 ± .02	1.2 ± .2
		7/30 & 10/30/69	13.3	.25 ± .01	1.6 ± .06
		9/19/69	14.5	.26 ± .02	1.5 ± .07
		10/2/69	16.1	.24 ± .02	1.3 ± .07
Calvert Beach:.....	Patuxent	12/12/69	15.1	.14 ± .02	.8 ± .1
		9/10/68	15.2	.35 ± .02	2.0 ± .12
Chesapeake Bay Biology Laboratory (Solomons).....		2/18/69	15.9	.10 ± .02	.6 ± .05
		6/10/69	14.4	.20 ± .03	1.6 ± .3
		9/4/69	14.7	.29 ± .07	1.6 ± .4
Point Lookout:.....	Potomac	5/26/69	16.5	.18 ± .02	1.4 ± .2
		6/9/69	16.0	.22 ± .04	1.5 ± .3
		7/25/69	15.3	.27 ± .02	1.5 ± .2
		9/18/69	15.8	.30 ± .02	1.5 ± .2
		1/27/70	17.5	.33 ± .04	1.6 ± .2

^a Ranked in direction of fresh water flow (figure 1).

^b Proportional error is about 20 percent.

^c 0.0117 times salinity equals grams of potassium per liter.

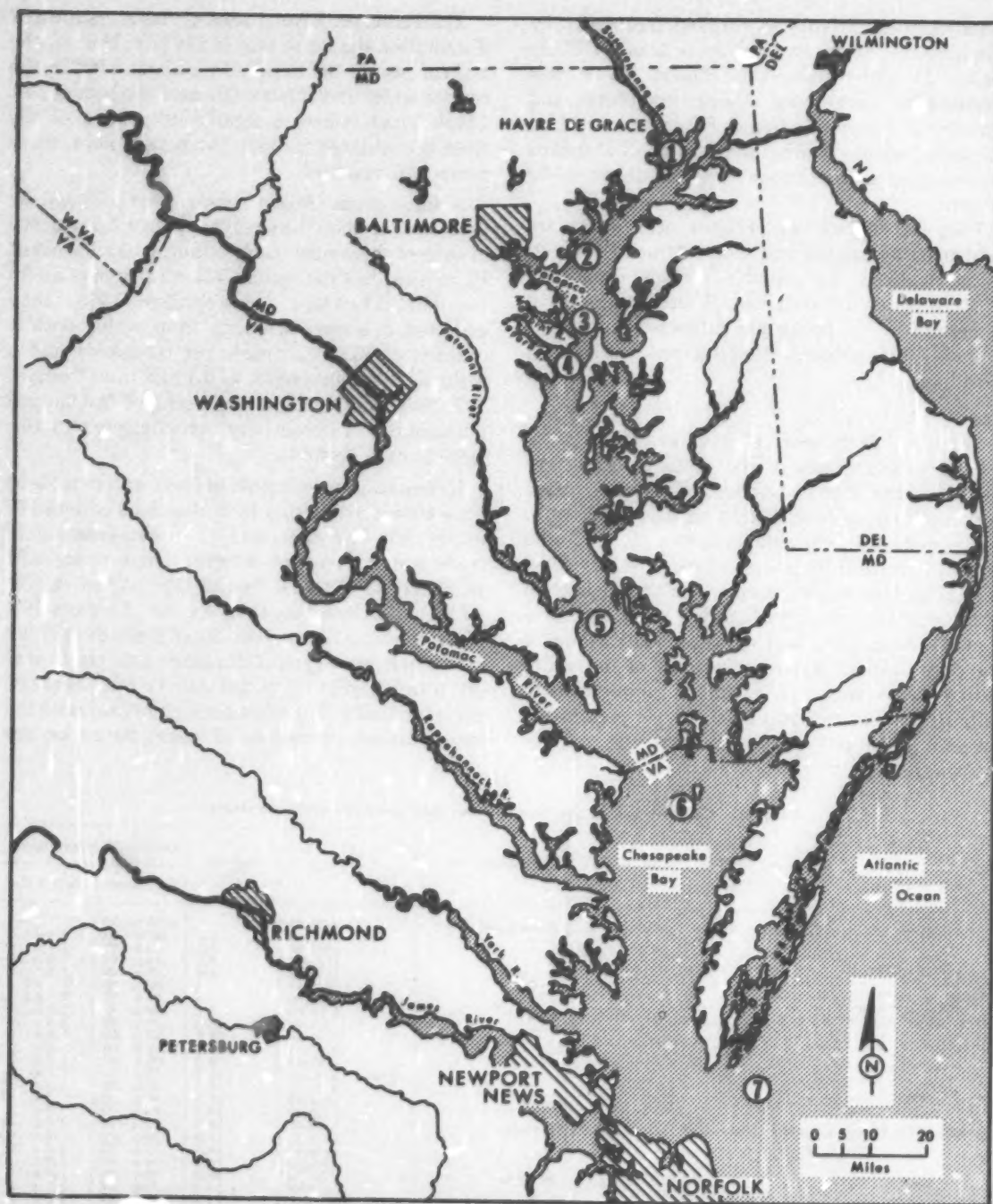


Figure 2. Chesapeake Bay cesium-137 stations, October 1968

Table 3. Cesium-137 in the Chesapeake Bay ship channel

Site ^a	Depth (feet)	Adjacent river	October 1969		Salinity ‰	Cesium-137 concentration	
			Day	Hour		(pCi/liter) ^b	(pCi/g K) ^c
1	6	Susquehanna	21	1040	4.5	0.06 ± 0.02	1.2 ± 0.4
2	Bottom	Patuxent	21	1140	4.5	.04 ± .02	.7 ± .3
3	Bottom	Patuxent	21	0830	12.9	.14 ± .02	.9 ± .1
4	Bottom	Magothy	21	1200	7.9	.06 ± .02	.7 ± .2
5	6	Severn	21	1630	13.9	.06 ± .02	.6 ± .1
6	106	Severn	22	0750	14.8	.24 ± .02	1.4 ± .3
7	6	Patuxent	22	0940	19.7	.12 ± .02	.6 ± .1
8	110	Patuxent	22	1220	23.0	.23 ± .02	1.2 ± .1
9	6	Potomac	22	1740	17.8	.18 ± .02	.7 ± .1
10	6	Potomac	22	1945	21.0	.23 ± .02	.9 ± .1
11	6	James	23	0750	19.0	.29 ± .02	1.3 ± .09
12	6	(In ocean)	23	1240	26.5	.17 ± .02	.6 ± .07
13	50	(In ocean)	23	1340	31.1	.14 ± .02	.4 ± .09

^a Ranked in direction of fresh water flow, see figure 2; bottom at fixed station: surface while underway.
^b Proportional error is about 20 percent.
^c 0.0117 times salinity equals grams of potassium per liter.

Table 4. Cesium-137 in Patuxent River^a

Site ^b	Depth (feet)		August 1969		Salinity ‰	Cesium-137 concentration	
	Start	End	Day	Hour		(pCi/liter) ^c	(pCi/g K) ^d
Milton Landing	2	2	7	1330	3.2	0.12 ± 0.02	3.1 ± 0.4
Potts Point	35	25	7	1110	3.3	.04 ± .02	.9 ± .3
Chalk Point	2	2	7	1110	7.7	.14 ± .02	1.8 ± .3
Chalk Point	6	7	8	1050	8.2	.06 ± .02	.9 ± .3
Buzzard Island	15	2	8	1050	8.7	.12 ± .02	1.1 ± .3
Buzzard Island	12	15	8	1305	9.3	.23 ± .02	2.0 ± .3
Drum Cliff	12	15	8	1305	10.9	.20 ± .02	1.7 ± .3
Drum Cliff	2	2	6	1340	11.6	.19 ± .02	1.4 ± .2
St. Cuthbert wharf	13	19	6	1340	12.8	.16 ± .02	1.1 ± .2
Drum Point	3	2	6	1140	13.5	.25 ± .02	1.6 ± .2
Drum Point	4	8	6	1140	13.7	.23 ± .02	1.3 ± .1
Drum Point	2	2	6	0920	14.5	.22 ± .02	1.3 ± .1
Drum Point	6	—	6	0920	14.7	.22 ± .02	1.3 ± .1

^a A bushel of clams collected on 2/17/69 off Marsh Point (salinity 13.3 ‰; cesium-137, 0.1 pCi/liter) contained 360 ± 20 pCi ¹³⁷Cs/kg dry meat.
^b 0.3 ± 0.2 pCi ¹³⁷Cs/g K.
^c Ranked in direction of fresh water flow.
^d Proportional error is about 20 percent.
^e 0.0117 times salinity equals grams of potassium per liter.

Table 5. Cesium-137 in the Chesapeake Bay tributary near shore

Site ^a	River	Date	Salinity ‰	Cesium-137 concentration	
				(pCi/liter) ^b	(pCi/g K) ^c
Delaware City	C & D Canal	1/30/70	6.4	0.07 ± 0.02	0.9 ± 0.3
Susquehanna State Park ^d	Susquehanna	4/5 & 11/68	.09	.00 ± .01	0 ± 10
Port Deposit	Susquehanna	5/14 & 16 and 6/10 & 11/68	.00 ± .008	.00 ± .008	—
Turkey Point	Elk	3/23/68	.10	.00 ± .04	0 ± 30
Elk Neck	Elk	4/11/68	.10	.07 ± .4	60 ± 30
Elk Neck	Elk	4/26/68	.27	.03 ± .02	9 ± 6
Baltimore	Northeast	4/19/68	.1	.00 ± .03	0 ± 20
Annapolis	Back	5/10/68	Brackish	.3 ± .07	—
Highway 4	Severn	4/22/68	Brackish	.04 ± .02	—
Bonadict	Patuxent	5/8/68	Fresh	.20 ± .02	—
Washington	Patuxent	7/29/68	Fresh	.20 ± .02	—
Washington	Potomac	7/30/68	Brackish	.3 ± .02	—
Washington	Potomac	2/18/69	18.0	.09 ± .02	.9 ± .1
Washington	Potomac	5/2 & 6/68	Fresh	.02 ± .01	—
Washington	Potomac	7/17/68	Fresh	.04 ± .02	—
Washington	Potomac	7/26/68	Fresh	.00 ± .02	—

^a Ranked in direction of fresh water flow.
^b Proportional error is about 20 percent.
^c 0.0117 times salinity equals grams of potassium per liter.
^d Other negative results (0 ± 20 pCi/sample) in Susquehanna River include filters, mixed resin, kilogram samples of mud and leaves, and 6 more extractions made at above sites, one with nitric acid added to maintain pH = 2.

Table 6. Cesium-137 in North Carolina estuaries

Site ^a	Body of water	August 1968		Salinity ‰	Cesium 137 concentration	
		Day	Hour		(pCi/liter) ^b	(pCi/g K) ^c
Radiobiology Laboratory, Beaufort	Bogue Sound	14	1400	35.6	0.16 ± 0.02	0.4 ± 0.05
New Bern	Neuse River	15	1100	7.9	.25 ± .02	2.9 ± .2
Fort Point	Neuse River	15	1400	7.0	.29 ± .02	3.5 ± .3
Croatan State Forest	Neuse River	14	1100	13.1	.22 ± .02	2.1 ± .3
Great Neck Point	Neuse River	15	1240	16.2	.34 ± .03	1.8 ± .1

^a Ranked in direction of fresh water flow.^b Proportional error is about 20 percent.^c 0.0117 times salinity equals grams of potassium per liter.

Surface water in the Neuse River was sampled from shore at four stations from New Bern downstream about 27 miles, almost to Pamlico Sound. Salinity during this test was 3 to 4 ‰ higher than that normally found by RBL investigators. Concentrations of cesium-137 in the Neuse River (table 6) were somewhat higher than in the Chesapeake Bay. The cesium to potassium ratio instead of being constant was a linear function of salinity, that is: pCi/g = 0.18 (25 - salinity). The radiocesium concentration and salinity of Bogue Sound were typical of coastal ocean water.

The Savannah River (table 7) receives a little cesium-137 from the AEC Savannah River project and is the only fresh water where we have found cesium-137 concentrations of more than 0.1 pCi/liter (other than in the discharge of a nuclear reactor). At the river's mouth, the concentration was lower, indicating dilution and rapid flushing.

Table 7. Cesium-137 in Savannah River

Site ^a	Date	Salinity	Cesium-137 concentration (pCi/liter) ^b
Augusta, Ga.	1/24/68	Fresh	0.1 ± 0.01
Below Savannah River plant	1/25/68	Fresh	.5 ± .05
Savannah, Ga: Ft. Pulaski	1/27/68	High tide	.1 ± .05
		Low tide	.2 ± .04

^a Ranked in direction of fresh water flow.^b Proportional error is about 20 percent.

Coastal Atlantic Ocean water (table 8) shows considerable variation in cesium-137 concentration. Lower concentrations are typical of ocean water, while higher concentrations are typical of water that has remained in a shallow basin. At Indian River Inlet either condition may exist depending on the flow during the test.

Table 8. Cesium-137 in coastal Atlantic Ocean

Site	Date	Cesium-137 concentration (pCi/liter) ^a
Indian River Inlet, Delaware	1/18/67	0.10 ± 0.01
	3/23/67	.24 ± .02
	3/28/67	.27 ± .02
	3/30/67	.13 ± .03
	4/30/67	.30 ± .04
	4/27/67	.07 ± .04
	5/17/67	.30 ± .06
Cape Henlopen, Delaware	6/14/67	.15 ± .02
	4/4/67	.21 ± .05
	8/6/67	.115 ± .004
Bahamas and Gulf Stream	11/18-19/68	.083 ± .005

^a Proportional error is about 20 percent.

Conclusions

Chesapeake Bay waters with salinity between 6 and 18 parts per thousand had cesium-137 concentrations between 0.1 and 0.4 pCi/liter. The concentration of dissolved fallout cesium-137 in fresh water averages less than 0.01 pCi/liter; in the coastal Atlantic Ocean, it is about 0.1 pCi/liter (7). The cesium-137 to potassium ratio is 1 to 2 pCi/g in the estuaries and about 0.5 pCi/g in the ocean. At salinities below 3 parts per thousand, the cesium to potassium ratio is subject to large errors because the assumption that potassium is a constant fraction of salinity does not hold for fresh water.

Two large reservoirs, the earth and the stratosphere, feed cesium-137 into the bay and will continue to do so for decades after the end of the atmospheric weapon tests. First, annual fallout directly on the bay's surface is about 2 nCi/m². Second, rain falling on 65,000 square miles of land drains into the Chesapeake Bay. So far, most of the cesium in that rain has been retained on the land because cesium is bound tightly to clay minerals. However, as these minerals wash into the bay, we may see estuarine concentrations of cesium-137 increasing even while fallout deposition

is decreasing. In salt water, sodium exchanges with cesium on clay so that part of the cesium is dissolved. To date, the cesium-137 in the Chesapeake Bay may be accounted for by the 6.5 meter average depth and 1 year's residence time:

$$(V) \frac{dc}{dt} = (2 \times 10^3 \text{ pCi/a} \cdot \text{m}^2)(\text{surface area}) - (Q)(C_i) = 0 \quad \dots(1)$$

where V = average volume of bay

Q = net flow rate from the bay

C_i = cesium-137 concentration in the bay

$$\text{surface area} = (V)/(d) \quad \dots(2)$$

where d = average depth

$$\therefore (2 \times 10^3)(V)/(d) = (Q)(C_i) \quad \dots(3)$$

$$\text{or } (2 \times 10^3)/(d) = (Q/V)(C_i) = (1/T)C_i \quad \dots(4)$$

where T = residence time

C_i = equilibrium cesium-137 concentration

$$\frac{(2 \times 10^3)(T)}{d} = C_i \quad \dots(5)$$

$$C_i = \left(\frac{2 \times 10^3 \text{ pCi/a} \cdot \text{m}^2}{6.5 \text{ m}} \right) \left(\frac{1 \text{ m}^3}{10^3 \text{ liter}} \right) (1 \text{ a})$$

$$= 0.3 \text{ pCi/liter} \quad \dots(6)$$

Fallout on the ocean surface is mixed to a depth of about 100 m, and the resulting cesium-137 concentration is about 0.1 pCi/liter. This observation suggests that the residence time for fallout cesium in the upper layer of the ocean may be on the order of:

$$1 \text{ year} \left(\frac{0.1 \text{ pCi/liter}}{0.3 \text{ pCi/liter}} \right) \left(\frac{100 \text{ meters}}{6.5 \text{ meters}} \right)$$

$$= 5 \text{ years} \quad \dots(7)$$

Acknowledgments

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We wish particularly to thank those individuals from Pennsylvania to Georgia who allowed us access to the water from their property; that we were never refused indicates a universal interest of watermen in understanding and protecting this resource.

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Nassau County Microwave Oven Study, June 1969-March 1970

David Mafri, Sheldon V. Bernstein, and Charles E. Miller¹

The Radiological Health Section of the Nassau County Department of Health conducted a survey of microwave ovens located in Nassau County, New York. A total of 166 ovens were surveyed between June 1969 and March 1970. It was found that 23 of the 166 ovens (14 percent) exceeded the industry's standard of 10 mW/cm² during normal operation. When the door was in the process of being opened, 69 of the 166 ovens (42 percent) exceeded the standard. The owners and the manufacturers of the ovens were notified of the results of the survey, and recommendations were made for correction of deficiencies.

Microwave equipment has been in wide use by the military for many years to convey information (such as radar and communications systems), as a means of transmitting power, and for heating effects (1). Recently, there has been an increase in the use of microwave radiation (microwave ovens) for food preparation. Although the use of microwave ovens had predominantly been limited to the military and commercial restaurants, units are now available for home use.

The current selling price ranges from \$500 to \$1,000 per oven and it was estimated in 1968 that sales approximated 40,000 units per year (2). Should the price decrease considerably, the number of ovens sold for home use is expected to increase sharply. The advantages of microwave cooking as compared to the conventional methods of cooking include: (a) shorter cooking time; (b) uniform cooking of the food rather than cooking only from the surface; (c) less need for cleaning of utensils since only the food is heated, and (d) production of less heat thereby keeping cooking areas cooler.

Effects of microwave radiation

Microwaves produce a rapid temperature rise in food, and this same effect would occur in the

human body. Microwave absorption is greatest in those tissues of the body which have a high water content. The biological effects of microwave radiation are greatest in tissues or organs which have a poor capacity to dissipate a local temperature rise. The male gonads and the lens of human eyes fall into this category. The eyes are especially susceptible and there is evidence that microwave radiation produces cataracts (3). There have not been any injuries reported which can be directly attributed to the use of microwave ovens; however, the potential for such injury exists (4). Although no official Federal standards have been promulgated,² the U.S. Army, Navy, and Air Force have established an exposure standard of 10 mW/cm², based on "heat tolerance and transfer capabilities of the human body" (5). The U.S.S.R.'s standard of 0.01 mW/cm² is based on "disruptions of the functional state of the neural and cardiovascular systems" (5). In the absence of official regulations, industry has accepted and used 10 mW/cm² as a voluntary emission standard.

Initial survey

As a result of discussions held with representatives of the U.S. Public Health Service, the Radiological Health Section of the Nassau County

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² Editors note: on October 6, 1970, emission standards for microwave ovens were published by the Bureau of Radiological Health.

Department of Health conducted a preliminary survey of microwave ovens during June 1969 (6). The purpose was to determine if a problem existed with ovens leaking microwave radiation in excess of industry's own standard. Initially, this study concentrated its efforts on commercial establishments. With the cooperation of three catering firms, the locations of commercial ovens in Nassau County were obtained. In addition, one of the oven manufacturers who produced ovens solely for home use submitted a list of customers located in the county. As a result of the June survey, it was discovered that 12 percent of the ovens exceeded industry's own standard of 10 mW/cm² at 5 cm during normal operation (door closed), and 40 percent exceeded the standard while the door was in the process of being opened (interlock test).

Subsequent survey

Since the 50 ovens surveyed in June could not be considered a representative sample, it was decided to extend the project and survey as many ovens as could be located in the county. In November 1969, a formal agreement was made with the U.S. Public Health Service and the New York State Department of Health in which the Nassau County Department of Health would perform the necessary surveys (7). One of the prime objectives of the agreement was to collect sufficient data for use in the development of performance standards for electronic products. In addition, the collection of these data could be used for county, State, and national assessment of radiation exposure from electronic products.

Survey procedures

A total of 166 microwave ovens were surveyed;—50 during June 1969 and 116 during December 1969 to March 1970 (table 1). Sixty-one of the ovens were located in commercial establishments (such as restaurants and cafeterias); 96 were being used in the home and nine used as demonstration models.

Two different instruments were used in the June survey, the Ramcor 1200B and the Narda 8100 (table 2). The Narda instrument was eventually selected and used throughout the later survey because:

- it was manufactured specifically for surveying microwave ovens,
- the antenna is designed to minimize polarization sensitivity of the detector,
- the 2-inch spacer provided uniform distance from any external surface of the oven,
- the instrument read directly in mW/cm² rather than decibels,
- the larger scale face was easier to read,
- an audible signal could be set for any particular reading, and
- no warmup time was required.

Table 1. Microwave oven study, Nassau County Department of Health

Manufacturer	Dates of survey		Total
	June 1969	December 1969 to March 1970	
Amara.....	14	40	54
Tappan.....	1	32	33
Litton.....	18	10	28
Omnivend.....	13	13	26
General Electric.....	0	16	16
Raytheon.....	4	2	6
Hotpoint.....	0	1	1
International.....	0	1	1
Magic Chef.....	0	1	1
Summary.....	50	116	166

Table 2. Type of instrument used

Instrument used	Number of ovens surveyed	
	June 1969	December 1969 to March 1970
Ramcor 1200B alone.....	19	0
Narda 8100 alone.....	7	116
Ramcor and Narda.....	24	0

At first, each inspection was performed by a team of two public health sanitarians; however, with experience it was found that only one sanitarian was needed to conduct each inspection. A difficulty encountered at the beginning of the survey was that of obtaining lists of names and addresses of private owners of microwave ovens. For various reasons, these lists were unavailable from the oven manufacturers. However, a press release published in the local newspapers resulted in a direct response from many oven owners to the Nassau County Health Department. During the survey, various oven manufacturers compiled listings of their customers and forwarded these lists to the Health

Department. There was no problem obtaining a list of the commercial oven locations in the County since the three catering firms were very cooperative during the June 1969 and December 1969-March 1970 surveys.

The procedures used in the survey were those established by the U.S. Public Health Service (8) except that a 300-ml styrofoam cup was used for the water load instead of a 600-ml glass beaker. All measurements were made using a 275 ml water test load in the cooking cavity and readings were taken at 5 cm from the surface of the oven. Two sets of measurements were obtained in each survey. The first set of readings was obtained while the oven was in normal operation (door closed). These readings indicated the amount of microwave radiation leakage which could potentially be a source of continuous human exposure during operation. A second set of readings was made while the door was in the process of being opened. With the oven operating, the door was slowly opened and measurements taken until the interlock engaged and disconnected the power supply to the oven. This procedure was performed to determine the efficiency of the interlocks. This type of microwave radiation leakage is considered to be a potential source of intermittent human exposure.

Results

The survey results show that 23 of 166 ovens (14 percent) exceeded industry's standard of 10 mW/cm² during normal operation (table 3).

Table 3. Results of survey measurements, door closed (normal operation)

Manufacturer	Reading (mW/cm ² at 5 cm from surface)				
	≤1	>1 ≤ 5	>5 ≤ 10	>10	Total
Amana.....	42	11	1	0	54
Tappan.....	9	12	10	2	33
Litton.....	8	10	4	0	22
Omnivend.....	4	13	2	7	26
General Electric.....	1	7	3	5	16
Raytheon.....	2	0	2	2	6
Hotpoint.....	1	0	0	0	1
International.....	1	0	0	0	1
Magic Chef.....	0	0	0	1	1
Total.....	68	53	23	23	166

When the door was in the process of being opened, 69 out of 166 ovens (42 percent) exceeded the standard (table 4).

Table 4. Results of survey measurements, door in the process of opening

Manufacturer	Readings (mW/cm ² at 5 cm from surface)				
	≤1	>1 ≤ 5	>5 ≤ 10	>10	Total
Amana.....	9	28	11	6	54
Tappan.....	0	2	3	2	22
Litton.....	0	5	3	16	24
Omnivend.....	0	7	1	8	26
General Electric.....	2	0	1	3	16
Raytheon.....	1	0	0	0	1
Hotpoint.....	1	0	0	0	1
International.....	1	0	0	0	1
Magic Chef.....	0	0	0	1	1
Total.....	30	44	23	60	166

There is very little difference in the results obtained in the initial survey (50 ovens in June) and the results obtained in the survey of 166 ovens (table 5).

Table 5. Comparison of results from the initial survey of 50 microwave ovens and survey of 166 microwave ovens

Test conditions	Percent exceeding 10 mW/cm ²	
	Initial June 1969 survey	June 1969 to March 1970 survey
Oven operating under normal conditions (door closed).....	12	14
Oven operating with door in process of being opened.....	40	42

These results generally agree with those compiled by other agencies throughout the nation where microwave oven studies have been performed (5).

After each survey, the owner of the oven was notified of the results. When the microwave leakage was found to exceed the voluntary standard, the owner was advised to discontinue the use of the oven and to contact the manufacturer to have the oven repaired. Where the readings were between 5 and 10 mW/cm², it was recommended that the ovens be serviced to reduce the leakage. Upon completion of the survey, each oven manufacturer was notified of the results of the survey of all his ovens. The notification included a listing of the oven location, the date of survey, the model number, measurements with the door closed, and measurements with the door in the process of being opened.

Discussion

The Nassau County microwave oven survey

revealed that some problems exist with microwave radiation leakage. On the basis of these survey results, it is recommended that a program be initiated to eliminate this unnecessary leakage. The initial phase of the program would be related to ovens that have been manufactured and are being used by the public. A second phase would relate to the manufacture of future ovens.

The initial phase, that of locating and surveying the ovens, was completed and the oven manufacturers notified of the results. It is now necessary to determine whether corrections have been made to those ovens which exceeded the industry's standard, and on this basis a followup survey is planned.

Ovens that will be manufactured in the future can be effectively controlled only by the passage of Federal legislation. The Nassau County Department of Health has recommended to the Secretary of Health, Education, and Welfare that all new microwave ovens be designed to meet a standard of 5 mW/cm² at 5 cm from any portion of the surface. The survey revealed that 58 percent of the ovens met industry's voluntary standard of 10 mW/cm² and that 45 percent were also equal to or less than 5 mW/cm². This is an indication that industry is capable of meeting a proposed standard of 5 mW/cm². In addition, a positive interlock system was recommended on all microwave ovens to insure that the power is turned off before the door is capable of being opened. If all ovens had a positive interlock system at the time of the survey, then 86 percent of the ovens would have met industry's standard of 10 mW/cm² and 73.5 percent would have met the Nassau County Health Department's recommended standard of 5 mW/cm².

The Ad Hoc Task Force Report (9) on microwave ovens has recommended that (based on available data on radiation leakage of microwave ovens) additional surveys be performed by industry and government. Each manufacturer plans to survey a percentage of their ovens and arrange for corrective servicing for any of the ovens which exceed industry's voluntary standard. The Radiological Health Section of the Nassau County Department of Health has completed a survey and forwarded the data to both the manufacturers and the U.S. Public Health Service. It is anticipated that these data will be used to develop performance standards and to assess the

nationwide radiation exposure from microwave ovens.

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Krypton-85 Levels in the Environment Determined from Dated Krypton Gas Samples

R. E. Shuping, C. R. Phillips, and A. A. Moghissi¹

A program to monitor the krypton-85 atmospheric concentrations in the United States is described, and concentrations of krypton-85 at several sites are presented. A brief description of the analytical method is given and values obtained are compared with those reported or predicted by others.

The Southeastern Radiological Health Laboratory has undertaken a program to monitor the krypton-85 concentration in the atmosphere utilizing dated krypton gas samples obtained from commercial suppliers. This program was undertaken to verify and monitor the trend of krypton-85 levels shown by Ehhalt et al. (1) and predicted by Coleman and Liberace (2). The latter predicted a dose rate of 50 millirads per year to the general population by 2060, based on a projected krypton-85 inventory. The krypton-85 content of the sample was determined using the method reported in reference 3. This method utilizes the high solubility of krypton in conventional organic liquid scintillation solutions. The gas is introduced into an evacuated glass vial fitted with a luer tapered, ground glass fitting. The vial is filled with deaerated scintillation solution and sealed with a plastic syringe hub. The vials are then counted in a liquid scintillation counter.

Since the receipt and reporting of the samples in reference 3, we have received dated krypton samples from Chester, W. Va., and Cleveland, Ohio. The samples from West Virginia were from monthly composites of gas, while those from Ohio were from quarterly composites. Three older samples of gas from Cleveland, Ohio, were received and were from yearly composites. The data obtained from these 17 samples are presented in table 1. The values in this table represent the mean

of five determinations on each sample. The data in table 2 were published in reference 3 and are reproduced here for comparison. The data from both tables are presented graphically in figure 1. The dates plotted in figure 1 are at the midpoint of the collection period and the activities are reported as pCi/m³ of dry air at standard temperature and pressure.

The solid line in figure 1 represents data published by Ehhalt et al. (1) in 1963 and indicates an upward trend in the krypton-85 levels. Coleman and Liberace (2) predicted an increase in the atmospheric levels of krypton-85 based on the anticipated use of nuclear energy. The values found during our work compare favorably with the upward trend seen by Ehhalt and the increase predicted by Coleman.

Table 1. Krypton-85 concentration in air (current SERHL data)

Sample origin	Midpoint of collection period	Radioactivity* (pCi/m ³)
Chester, W. Va.	6/69	14.0 ± 0.4
	7/69	13.6 ± .1
	8/69	13.8 ± .3
	9/69	13.6 ± .3
	10/69	13.6 ± .3
	12/69	13.7 ± .2
	1/70	13.1 ± .2
Cleveland, Ohio (Site A)	2/70	13.2 ± .2
	1/68	11.2 ± .2
	7/68	13.1 ± .2
	5/69	14.2 ± .2
	8/69	14.0 ± .5
Cleveland, Ohio (Site B)	12/69	14.5 ± .4
	3/70	14.9 ± .2
	4/62	7.2 ± .4
	11/62	7.6 ± .1
	7/64	10.3 ± .2

* Standard deviation calculated at the 95-percent confidence level. Mean of five determinations.

¹ Mr. Shuping and Mr. Phillips are with the Southeastern Radiological Health Laboratory, Montgomery, Ala., and Dr. Moghissi is with Southwestern Radiological Health Laboratory, Las Vegas, Nev.

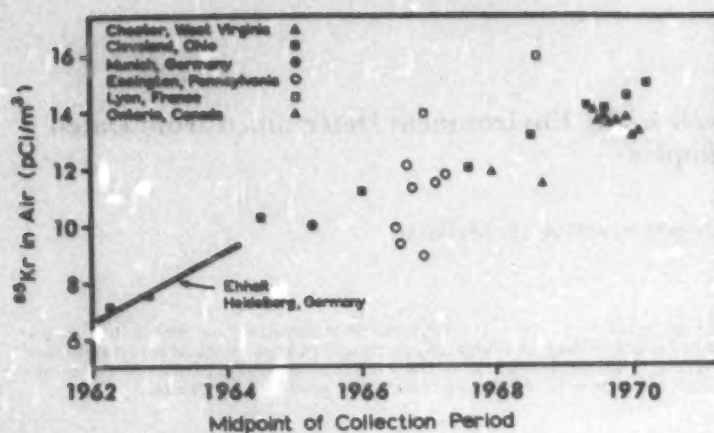


Figure 1. Krypton-85 concentration in air (including data of Ehhalt et al.)

Table 2. Krypton-85 concentration in air (from reference 3)

Sample origin	Midpoint of collection period	Radioactivity* (pCi/m ³)
Munich, Germany.....	4/65	10.1 ± 0.2
Emsington, Pa.....	7/66	9.9 ± .4
	8/66	9.3 ± .5
	9/66	12.1 ± .5
	10/66	11.3 ± .4
	12/66	8.9 ± .4
	2/67	11.5 ± .6
	4/67	11.8 ± .4
Lyon, France.....	12/66	15.9 ± .4
	2/68	15.9 ± .6
Cleveland, Ohio.....	8/67	12.0 ± .7
Ontario, Canada.....	12/67	11.8 ± .5
	9/68	11.4 ± .2

* Standard deviation calculated at the 95-percent confidence level. Mean of at least five determinations.

We plan to continue this project and will publish atmospheric krypton-85 concentrations periodically in this journal.

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SECTION I. MILK AND FOOD

Milk Surveillance, August 1970

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Bureau of Radiological Health and the Bureau of Compliance, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (1). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (2) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabol-



Figure 1. Milk sampling networks in the Western Hemisphere

ically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2-standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (3) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (4).

The most recent study was conducted during May–July 1970, with 28 laboratories participating

in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140 (5). Of the 20 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 13 participated in the experiment.

The accuracy results of this experiment are shown in table 1. In general, considerable improvement is needed, especially in the accuracy measurements. Keeping these possible differences in mind, integration of the data from the various networks can be undertaken.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration	Number of laboratories in each category			Total
	Acceptable ($X \leq \bar{X} \pm 2\sigma$)	Warning level ($\bar{X} \pm 2\sigma < X < \bar{X} \pm 3\sigma$)	Unacceptable ($X \geq \bar{X} \pm 3\sigma$)	
Strontium-89: High (255 pCi/liter)	7 (44%)	1 (6%)	8 (50%)	16
Low (15 pCi/liter)	11 (60%)	3 (19%)	2 (12%)	16
Strontium-90: Intermediate (79.4 pCi/liter)	13 (57%)	4 (17%)	6 (26%)	23
Low (32.0 pCi/liter)	5 (26%)	4 (30%)	11 (56%)	20
Iodine-131: High (507 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (49 pCi/liter)	16 (64%)	3 (12%)	6 (24%)	25
Cesium-137: High (259 pCi/liter)	20 (74%)	3 (11%)	4 (15%)	27
Low (53 pCi/liter)	17 (68%)	5 (19%)	4 (15%)	26
Barium-140: High (302 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (23 pCi/liter)	23 (92%)	0	2 (8%)	25

and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A previous article (6) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short time periods, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. An analysis (7) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that, for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses (8). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose

practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (9). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1-5 pCi/liter for levels <50 pCi/liter; 5-10% for levels ≥50 pCi/liter;
Strontium-90	1-2 pCi/liter for levels <20 pCi/liter; 4-10% for levels ≥20 pCi/liter;
Iodine-131 } Cesium-137 } Barium-140 }	4-10 pCi/liter for levels <100 pCi/liter; 4-10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below

Radiation Protection Guides (8, 9)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result due to exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 2 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (3).

In the absence of specific dietary data, one can

use milk as the indicator food item for routine surveillance. Assuming a 1 liter per day intake of milk, one can utilize the graded approach of daily intake on the basis of radionuclide content in milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Protective Action Guides (10, 11)

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1 or 2-year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 3 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier (3). Also given in table 3 are milk concentrations for each

Table 2. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Nuclide	Critical organ	RPG for individual in the general population (rad/a)	Guidance for suitable samples of exposed population groups				
			RPG (rad/a)	Corresponding continuous daily intake (pCi/day)	Range I (pCi/day) ^a	Range II (pCi/day) ^a	Range III (pCi/day) ^a
Strontium-90	Bone	1.5	0.5	42,000	0-300	300-2,000	2,000-20,000
Strontium-90	Bone marrow	.5	.17				
	Bone marrow	1.5	.5	4200	0-30	30-300	200-2,000
	Bone marrow	.5	.17				
Iodine-131	Thyroid	1.5	.5	100	0-10	10-100	100-1,000
Cesium-137 ^c	Whole body	.5	.17	3,600	0-300	300-3,600	3,600-36,000

^a Suitable samples which represent the limiting conditions for this guidance are: strontium-90, strontium-90—general population; iodine-131—children 1 year of age; cesium-137—infants.

^b Based on an average intake of 1 liter of milk per day.

^c A dose of 1.5 rad/a to the bone is estimated to result in a dose of 0.5 rad/a to the bone marrow.

^d For strontium-90 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.

^e The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

Table 3. Protection Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-90.....	Bone marrow	10 in first yr; total dose not to exceed 15 ^{a,b}	3 in first yr; total dose not to exceed 5 ^{a,b}	• 1,110,000 • 51,000 • 730,000
Cesium-137.....	Bone marrow			
Iodine-131.....	Thyroid	30	10	• 70,000

^a The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.

^b Total dose from strontium-90 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.

^c These values represent concentrations that would result in dose to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.

^d This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

of the radionuclides considered, in the absence of others, which, if attained after an acute incident, would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the pasture-cow-milk-man pathway, as well as an estimate of the intake prior to reaching the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in retrospective manner.

Data reporting format

Table 4 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. The relationship between the PMN stations and State stations is shown in figure 2. The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of

radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed populations groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 4, surveillance results are given for strontium-90, iodine-131, and cesium-137 for August 1970 and the 12-month period, September 1969 to August 1970. Except where noted the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 4 since levels at the great majority of the stations for August 1970 were below the respective practical reporting levels. Table 5 gives monthly averages for those stations at which strontium-89 was detected.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 2), levels in milk for this radionuclide are

Table 4. Concentration of radionuclides in milk for August 1970 and 12-month period, September 1969 through August 1970

Sampling location		Type of sample	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average	12-month average	Monthly average	12-month average	Monthly average	12-month average
UNITED STATES:								
Ala:	Montgomery	NA	6	0	0	0	14	
Ala:	Palmer	7	8	0	0	0	16	
Ariz:	Phoenix	0	1	0	0	0	0	
Ariz:	Little Rock	14	13	0	0	0	18	
Ark:	Sacramento	0	0	0	0	0	0	
Cal:	San Francisco	NA	1	0	0	0	0	
	Del Norte	10	19	0	0	0	0	
	Fresno	1	5	0	0	0	0	
	Humboldt	3	3	0	0	0	0	
	Los Angeles	3	3	0	0	0	0	
	Mendocino	3	3	0	0	0	0	
	Sacramento	3	3	0	0	0	0	
	San Diego	3	3	0	0	0	0	
	Santa Clara	3	3	0	0	0	0	
	Shasta	3	3	0	0	0	0	
	Stanislaus	3	3	0	0	0	0	
	Tulare	NA	8	0	0	0	0	
	West	0	0	0	0	0	0	
	Northwest	0	0	0	0	0	0	
	East	0	0	0	0	0	0	
	Southwest	0	0	0	0	0	0	
	South Central	0	0	0	0	0	0	
	Southwest	0	0	0	0	0	0	
	Northwest	0	0	0	0	0	0	
Conn:	Hartford	NA	37	0	0	0	0	
	Central	8	7	0	0	22	10	
Del:	Wilmington	NA	8	0	0	0	12	
D.C.:	Washington	NA	7	0	0	0	17	
Fla:	Tampa	6	6	0	0	42	0	
	West	10	10	0	0	0	0	
	North	13	11	0	0	30	26	
	Northwest	4	0	0	0	10	20	
	Central	6	7	0	0	80	40	
	Tampa Bay area	6	7	0	0	44	31	
	Southwest	5	7	0	0	66	73	
Ga:	Atlanta	NA	10	0	0	0	NA	
Hawaii:	Honolulu	3	3	0	0	0	0	
Idaho:	Idaho Falls	3	3	0	0	0	0	
Ill:	Chicago	7	8	0	0	12	9	
Ind:	Indianapolis	NA	9	0	0	13	15	
	Northwest	9	13	0	1	20	14	
	Southwest	12	9	0	0	15	9	
	Central	11	11	0	0	15	12	
	Southwest	11	10	0	0	15	15	
Iowa:	Des Moines	NA	6	0	0	0	3	
	Iowa City	NA	7	0	0	0	NA	
	Des Moines	11(4)	5	0(4)	0	NA	5	
	Des Moines	NA	NA	NA	NA	NA	NA	
Kan:	Wichita	NA	7	0	0	NA	1	
	Colonyville	7	8	NA	NA	NA	2	
	Des Moines	13	7	NA	NA	NA	0	
	Paul City	ND	10	NA	NA	NA	0	
	Hays	10	12	NA	1	NA	1	
	Kansas City	ND	13	NA	0	NA	0	
	Topeka	13	9	NA	0	NA	0	
	Wichita	13	8	NA	0	NA	2	
Ky:	Louisville	NA	8	NA	0	NA	4	
La:	New Orleans	14	15	0	0	23	18	
Maine:	Portland	NA	10	0	0	37	22	
Mad:	Baltimore	NA	8	0	0	13	7	
Mass:	Seattle	10	10	0	0	26	21	
Mich:	Detroit	NA	9	0	0	15	12	
	Grand Rapids	NA	7	0	0	NA	9	
	Bay City	NA	7	0	0	NA	17	
	Charlottesville	13(4)	13	NA(5)	0	17(5)	7	
	Detroit	7	8	NA	0	NA	11	
	Grand Rapids	10	9	NA	0	14	16	
	Lansing	8	9	NA(2)	0	30	23	
	Marquette	12(2)	13	NA(2)	0	19	4	
	Marquette	6(2)	8	NA(2)	0	0	8	
	South Haven	7(2)	8	NA(2)	0	15	9	
Minn:	Minneapolis	NA	10	0	0	37	23	
	Minneapolis	7	12	0	0	10	11	
	Minneapolis	4	8	0	0	15	11	
	Minneapolis	7	7	0	0	10	11	
	Minneapolis	0	15	0	0	37	37	
	Minneapolis	11	8	0	0	0	0	
	Minneapolis	NA	10	0	0	NA	14	
	Minneapolis	7	7	0	0	3	13	
	Minneapolis	19	10	0	0	104	28	

^aSee footnotes at end of table.

Table 4. Concentration of radionuclides in milk for August 1970 and 12-month period, September 1969 through August 1970—Continued

[illegible]

See instructions at end of table.

Table 4. Concentration of radionuclides in milk for August 1970 and 12-month period, September 1969 through August 1970—Continued

Sampling location	Type of sample	Radionuclide concentration (pCi/liter)					
		Strontium-90		Iodine-131		Cesium-137	
		Monthly average ^a	12-month average	Monthly average ^a	12-month average	Monthly average ^a	12-month average
CANADA							
Alberta:	Calgary	P	NA	50		13	18
	Edmonton	P	NA	50		21	17
British Columbia:	Vancouver	P	NA	50		24	38
Manitoba:	Winnipeg	P	NA	50		29	34
New Brunswick:	Fredericton	P	NA	50		23	20
Newfoundland:	St. John's	P	NA	50		60	37
Nova Scotia:	Halifax	P	NA	50		28	30
Ontario:	Ottawa	P	NA	50		18	14
	Sault Ste. Marie	P	NA	50		43	28
	Thunder Bay	P	NA	50		43	28
	Toronto	P	NA	50		15	10
	Windsor	P	NA	50		11	10
Quebec:	Montreal	P	NA	50		23	18
	Quebec	P	NA	50		30	27
Saskatchewan:	Regina	P	NA	50		13	14
	Saskatoon	R	NA	50		23	13
CENTRAL AND SOUTH AMERICA:							
Colombia:	Bogota	P	0	0	0	0	0
Chile:	Santiago	P	0	0	0	0	0
Ecuador:	Guayaquil	P	0	0	0	0	0
Jamaica:	Mandeville	P	0	0	0	0	0
Venezuela:	Caracas	P	3	5	0	55	93
Costa Rica:	Crucial	P	3	1	0	0	0
Puerto Rico:	San Juan	P	NA	3	0	3	9
					0	14	6
PMN Network average^d							
			7	7	0	0	10

- ^a P, pasteurized milk; R, raw milk.
- ^b When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.
- ^c PHS Pasteurized Milk Network station. All other sampling locations are part of the State or National network.
- ^d Radionuclide analysis not routinely performed.
- ^e The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:
 Iodine-131: Colorado—36 pCi/liter
 Michigan—14 pCi/liter
 Oregon—15 pCi/liter
 Cesium-137: Colorado—25 pCi/liter
 New York—20 pCi/liter
 Oregon—15 pCi/liter
 Strontium-90: New York—3 pCi/liter
- ^f This entry gives the average radionuclide concentrations for the PHS Pasteurized Milk Network stations denoted by footnote ^c.
- ^g Monthly samples were collected and composited for quarterly analysis of strontium-90.
- NA, no analysis.
- NS, no sample collected.

Table 5. Strontium-90 in milk, August 1970

Sampling location	Radionuclide concentration (pCi/liter)
Calif: Del Norte (State)	5
Kans: Coffeyville (State)	13
N.Y.: Massena (State)	5(2)
Tenn: Chattanooga (State)	6
Knoxville (State)	31
Nashville (State)	6
Payetteville (State)	6
Colombia: Bogota (FAO)	10
Chile: Santiago (FAO)	20

of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 19 pCi/liter in the United States for the month

of August 1970, and the highest 12-month average was 19 pCi/liter (Del Norte, Calif.) representing 9.5 percent of the Federal Radiation Council radiation protection guide (table 2). Cesium-137 monthly averages ranged from 0 to 104 pCi/liter in the United States for the month of August 1970, and the highest 12-month average was 73 pCi/liter (Southeast Fla.) representing 2.0 percent of the value presented in this report using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (12) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting levels with the following exceptions: Colo., Northwest (State) 37 pCi/liter and S.C., Charleston (PMN) 11 pCi/liter.

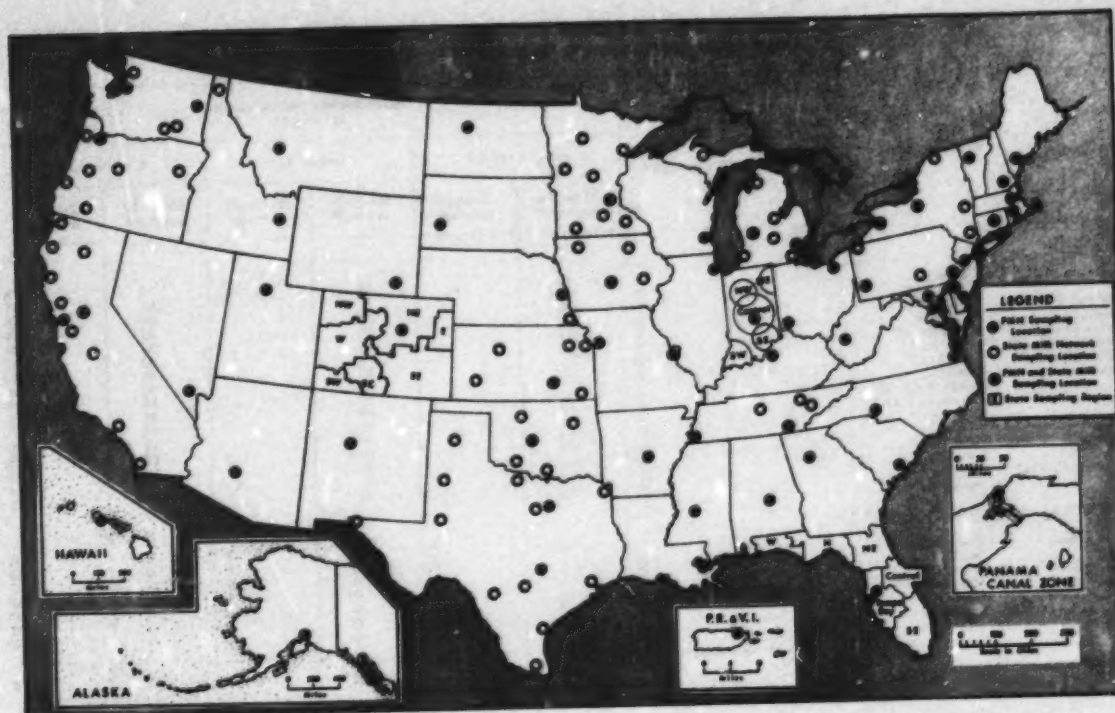


Figure 2. State and PMN milk sampling locations in the United States

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Division of Medical Services
Connecticut State Department of Health

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State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
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Conservation

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Radiological Health Section
Bureau of Environmental Health
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Radiological Health Services
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Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intake of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows.

Program	Period reported	Issue
California Diet Study	April-December 1969 and January-June 1970	November 1970
Institutional Diet Samples Strontium-90 in Tri-City Diets, HASL	January-March 1970 June-December 1969	November 1970 June 1970

1. Estimated Daily Intake of Radionuclides in Connecticut Standard Diet, July-December 1969

Connecticut State Department of Health

The Connecticut State Department of Health has been analyzing a standard diet on a monthly basis since March 1963. Analyses are made for strontium-89, strontium-90, and gamma-ray emitters.

The standard diet was selected to represent the food intake of an 18-year-old boy for 1 day (table 1). The total weight of the complete blended diet, averaging 3 kilograms, included milk and dairy products. When raw fruit or vegetables were sampled, they were washed before blending.

Cesium-137 concentrations were determined by

Table 1. Foods included in standard diet

Bread, white—8 slices	Ice cream— $\frac{1}{2}$ pint
Butter— $\frac{1}{4}$ stick	Lettuce, washed—4-5 leaves
Carrots, chopped— $\frac{1}{4}$ cup	Milk—4 cups
Celery, washed and trimmed—3 stalks	Oatmeal—uncooked—43 grams
Cookies, 4	Orange—1
Cottage cheese— $\frac{2}{3}$ cup	Peanut butter— $2\frac{1}{2}$ tablespoons
Cupcake, 2	Pears, canned—2 halves with juice
Egg, 1	Potatoes, washed, not peeled—3
Green beans, washed— $\frac{1}{4}$ cup	Rice—3 tablespoons
Ham, 66 grams	Tomato juice—113 grams
Hamburger, 277 grams	Tuna fish, drained—43 grams

gamma-ray spectrometry (1). Strontium-89 and strontium-90 concentrations were determined by chemical separation techniques (1).

Table 2 presents the analytical results for the Connecticut standard diet for July-December 1969. Results representative of the total daily intake for the radionuclides observed are presented in table 3.

Table 2. Radionuclide concentrations in Connecticut standard diet*, July-December 1969

Month (1969)	Potassium (g/kg)	Strontium-90 (pCi/kg)	Cesium-137 (pCi/kg)
July.....	2.1	8.5	10
August.....	NA	NA	NA
September.....	2.0	5.1	20
October.....	NA	NA	NA
November.....	NA	NA	NA
December.....	2.1	7.7	30

* All strontium-90 values were <3 for this period.
NA, no analysis.

In order to evaluate general trends, the strontium-90 and cesium-137 daily intakes are plotted as a function of time in figures 1 and 2.

Table 3. Daily radionuclide intakes in Connecticut standard diet,* July-December 1969

Month (1969)	Potassium (g/day)	Strontium-90 (pCi/day)	Cesium-137 (pCi/day)
July.....	8.4	28.9	40
August.....	NA	NA	NA
September.....	8.8	17.1	60
October.....	NA	NA	NA
November.....	NA	NA	NA
December.....	7.0	25.3	70

* All strontium-90 values were <1 for this period.
NA, no analysis.

REFERENCE

(1) CONNECTICUT STATE DEPARTMENT OF HEALTH. Estimated daily intake of radionuclides in Connecticut standard diet, March 1963-December 1964. Radiol Health Data 6:361-382 (July 1965).

Recent coverage in Radiological Health Data and Reports:

Period	Issue
January-June 1969	February 1970

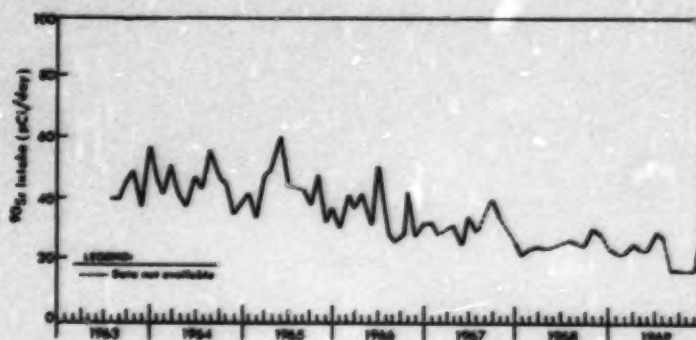


Figure 1. Strontium-90 intake in Connecticut standard diet 1963-December 1969

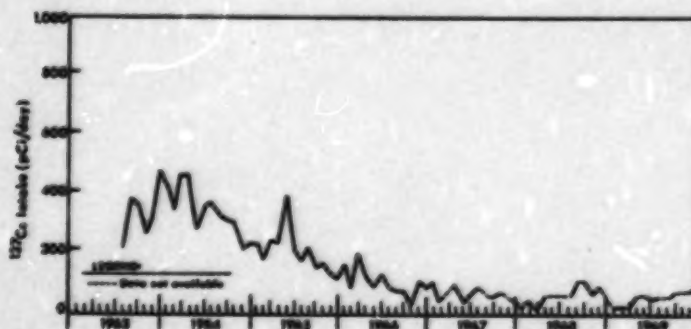


Figure 2. Cesium-137 intake in Connecticut standard diet 1963-December 1969

SECTION II. WATER

The Public Health Service, the Federal Water Quality Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (1). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (3-4), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total

intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence¹ of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

¹ Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	July-December 1968	August 1970
Minnesota	January-June 1969	January 1970
New York	January-June 1969	June 1970
Kansas	January-December 1969	September 1970
North Carolina	January-December 1967	May 1969
Radiostrontium in Tap Water, HASL	January-December 1969	July 1970
Tritium in Surface Water	January-June 1970	November 1970
Washington	July 1967-June 1968	June 1969

REFERENCES

- (1) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).
- (2) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies, Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

- (3) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).
- (4) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

INTERSTATE CARRIER DRINKING WATER ANALYSIS PROGRAM, 1967-1969

*Bureau of Water Hygiene and Bureau of Radiological Health
U.S. Public Health Service*

The routine surveillance of finished drinking water from public drinking water supplies has been a project of the Public Health Service's Bureau of Water Hygiene¹ since 1960, in partial fulfillment of the requirements as set forth in Subpart J of the Interstate Quarantine Regulation (1) most commonly referred to as the Public Health Service Drinking Water Standards. The basic network for this activity is approximately 665 water supplies (serving over half of the U.S. population with access to public water systems) which provide water for use by interstate carriers. Laboratory support is provided by the Northeastern, Southeastern, and Southwestern Radiological Health Laboratories of the Bureau of Radiological Health. For the most part, samples were composited over a 14-day period, taking 90 milliliters three times during the operating day; however, as indicated in table 1, many samples were also taken as a single grab sample. In many cases where a water system receives raw water from more than one source, the finished drinking water derived from each source has been examined.

The drinking water standards for radionuclides are conservative in their requirements, so that

the total intake of these radionuclides from all sources is not likely to result in an intake greater than the guidance levels given by the Federal Radiation Council (2).

The standards provide for the approval of water supplies, based on their radionuclide content, when the water does not contain more than 3 pCi/liter of radium-226 or 10 pCi/liter of strontium-90. In the absence of strontium-90, and in the absence of alpha emitters, the water supply is acceptable when the gross beta concentration does not exceed 1,000 pCi/liter.

However, a water supply may be approved when the limits prescribed above are exceeded if it can be demonstrated by surveillance that the total intake of radioactivity from all sources is within the guidance for control action recommended by the Federal Radiation Council. When mixtures of radionuclides are present, the relative contribution of each radionuclide to the total intake of the individual should be considered when evaluating the exposure.

Table 1 provides the results of the radiological analyses and table 2 is a summary of the results. It should be noted that the interstate carrier water samples for March through October 1969 were collected in conjunction with the Bureau of Water Hygiene's Community Water Supply Study.

¹ Formerly the Water Supply and Sea Resources Program, National Center for Urban and Industrial Health.

Table 1. Radiological analyses of Interstate Carrier water supplies, 1967-1969

Sampling location	Sampling periods	Total radium (pCi/liter)	Radium-226 (pCi/liter)	Radium-228 (pCi/liter)	Gross alpha radioactivity (pCi/liter)		Gross beta radioactivity (pCi/liter)	
					Dissolved	Suspended	Dissolved	Suspended
Ala:	Anniston.....	6/8/67	0	0	0	0	0	0
	Florence.....	10/28/68	0	0	0	0	0	0
	Mobile.....	5/21-6/4/67	0	0	0	0	0	0
	Montgomery (N. Court Street).....	4/29/68	0	0	0	0	0	0
	Montgomery (Day Street).....	4/29/68	0	0	0	0	0	0
	Montgomery (Perry Plant).....	4/29-5/15/68	0	0	0	0	0	0
	Prichard.....	8/23-9/5/67	0	0	0	0	0	0
Alaska:	Bedford.....	5/8/67	0	0	0	0	3	0
	Anchorage.....	9/19/67	0	0	0	0	3	0
	Fairbanks (Treatment Plant).....	9/27/67	0	0	3	0	0	0
	Fairbanks (Sally's Catering).....	9/27/67	0	0	0	0	4	0
	Fairbanks (International airport).....	9/27/67	0	0	0	0	4	0
	Juneau (Airport facility).....	9/27/67	0	0	0	0	4	0
	Juneau (Port facility).....	9/29/67	0	0	0	0	0	0
Ark:	Ketchikan.....	10/2/67	0	0	0	0	0	0
	Fayetteville.....	10/9/68	0	0	0 (total)	0	3 (total)	0
	Pt. Smith.....	10/9/68	0	0	0 (total)	0	3 (total)	0
	Helena.....	10/9/68	0	0	0 (total)	0	3 (total)	0
	Little Rock (Little Rock Water works).....	10/1/68	0	0	0 (total)	0	3 (total)	0
	Little Rock (Oriskany Water plant).....	10/1/68	0	0	0 (total)	0	3 (total)	0
Calif:	W. Memphis.....	9/25/68	0	0	0 (total)	0	0 (total)	0
	Bartow.....	4/15/69	3	0	7 (total)	0	3 (total)	0
	Colton.....	3/20/69	0	0	2 (total)	0	3 (total)	0
	Ontario.....	3/25/69	0	0	0 (total)	0	3 (total)	0
	San Bernardino (7th Street plant).....	4/14/69	0	0	2 (total)	0	3 (total)	0
	San Bernardino (South and Devil Canyon).....	4/15-4/28/69	0	0	0 (total)	0	3 (total)	0
Colo:	Yermo.....	4/9/69	3	0	11 (total)	0	4 (total)	0
	Durango.....	6/21/68	0	0	0 (total)	0	0 (total)	0
Del:	Pueblo.....	6/11/69	0	0	0 (total)	0	10 (total)	0
	Seanton.....	4/27-5/7/67	0	0	0	0	15	0
	Wilmington.....	5/17-5/21/67	0	0	0	0	0	0
Fla:	Bay County.....	3/6-3/20/68	7.3	1.2	0	0	0	0
	Cocon.....	6/22-7/6/67	0	0	0	0	0	0
	Orlando (McCoy Air Terminal).....	2/3/69	0	0	0	0	0	0
	Orlando (Nubar Industries).....	2/9/69	0	0	0	0	3	0
	Orlando (Utilities Co. Plant).....	2/15-2/19/69	0	0	0	0	0	0
	Panama City.....	3/5/68	0	0	0	0	3	0
	Pensacola.....	12/5-12/12/68	0	0	0	0	4	0
	Port St. Joe.....	3/7-3/21/68	0	0	0	0	0	0
	St. Petersburg.....	10/1-10/2/68	0	0	0	0	0	0
	Tallahassee.....	9/7/68	0	0	0	0	0	0
	Tampa.....	10/14/68	0	0	0	0	0	0
	Tampa.....	10/5-10/29/68	0	0	0	0	0	0
	Tribby.....	10/9/68	0	0	0	0	4	0
	Wildwood.....	9/20/67	0	0	0	0	0	0
Ga:	Albany.....	3/15-3/16/67	3.0	0	0	0	0	0
	Albany (Light and Gas).....	3/15-3/16/67	0	0	0	0	3	0
	Macon.....	3/4-3/28/67	1.6	0	0	0	0	0
Ill:	Argo.....	9/10-9/24/68	0	0	0	0	0	0
	Beardstown.....	8/9-8/20/68	0	0	0	0	3	0
	Bedford Park.....	9/7-9/21/68	0	0	0	0	7	0
	Cairo.....	5/17-5/21/67	0	0	0	0	0	0
	Carbondale.....	5/23-6/4/67	0	0	0	0	0	0
	Danville.....	9/4-9/18/68	0	0	0	0	4	0
	Dawson's Grove.....	2/23-3/5/67	0	0	0	0	7	0
	Franklin Park.....	10/22-11/4/68	0	0	0	0	33	4
	Harriburg.....	9/20-10/12/68	0	0	0	0	0	0
	Hartford.....	9/20-9/12/68	0	0	0	0	4	0
	Lemont.....	7/24-8/12/68	11.9	0	7	0	3	0
	Lemont.....	1/27-2/13/69	11.6	0	28	0	31	0
	Moline.....	5/1-5/14/67	0	0	0	0	47	0
	Mr. Vernon.....	11/8-11/23/68	0	0	0	0	0	0
	Orland Park.....	7/24-8/7/68	0	0	0	0	0	0
	Rock Island.....	4/28-5/12/67	0	0	0	0	3	0
	Rosemont.....	9/5-9/19/68	0	0	3	0	6	0
	Springfield.....	7/18-8/11/68	0	0	0	0	0	0
	Vandalia.....	8/8-8/23/63	0	0	0	0	3	0
Ind:	Middlebury.....	10/29/68	0	0	0	0	0	0
	W. Lafayette.....	9/20-10/7/68	0	0	0	0	0	0
Ky:	Covington.....	5/5-5/10/69	0	0	0 (total)	0	0 (total)	0
	Winston Park.....	3/6-3/19/69	0	0	0 (total)	0	0 (total)	0

See footnote at end of table.

Table 1. Radiological analyses of Interstate Carrier water supplies, 1967-1969—Continued

Sampling location	Sampling periods	Total radium (pCi/liter)	Radium-226 (pCi/liter)	Strontium-90 (pCi/liter)	Gross alpha radioactivity (pCi/liter)		Gross beta radioactivity (pCi/liter)	
					Dissolved	Suspended	Dissolved	Suspended
La:	Chalmette	6/19-7/3/69	0	0	0 (total)	0	0 (total)	0
	Gretna	6/19-6/27/69	0	0	0 (total)	0	0 (total)	0
	Madisonville	6/23/69	0	0	0 (total)	0	0 (total)	0
	New Orleans	6/23-7/3/69	0	0	0 (total)	0	0 (total)	0
	New Orleans	6/23-7/3/69	0	0	0 (total)	0	0 (total)	0
	New Orleans	6/19-7/3/69	0	0	0 (total)	0	0 (total)	0
Md:	Westview	6/17-6/30/69	0	0	0	0	4	0
	Chambray	11/4/69			0	0	7	0
	(Hampshire aquifer)	11/4/69			0	0	7	0
Mich:	Chambray	11/4/69			0	0	7	0
	Flinty Point aquifer	11/4/69			0	0	7	0
	Flinty Point	11/4/69			0	0	7	0
	Flinty Point	11/4/69			0	0	7	0
	Williamport	2/12-4/3/69			0	0	5	0
	Calumet	6/31-6/19/69			0	0	5	0
	Channing	6/14-6/26/69			0	0	0	0
	Detroit	6/14-6/26/69			0	0	0	0
	Edmore	6/2-7/11/67			0	0	0	0
	Holland	6/29-7/12/67			0	0	0	0
	Lansing	6/23-10/7/69			0	0	0	0
	West County	7/6-7/23/67			0	0	0	0
Miss:	Madison	6/27-7/11/67			0	0	2	0
	St. Joseph	6/2-6/16/69			0	0	0	0
	Wynning	6/23-7/11/67			0	0	0	0
	Gulfport	12/6/67			0	0	0	0
	(5th Avenue well)	12/7/67			0	0	0	0
	Gulfport	12/7/67			0	0	4	0
	Greenfield	3/25/69			0	0	0	0
	Jackson	3/27/69			0	0	7	0
	Meridian	4/15/69			0	0	2	0
	Miss Point	3/23/69			0	0	0	0
	Natchez	3/23/67	2.0	0	0	0	0	0
	Pascagoula	3/23/67	1.3	0	0	0	0	0
Mo:	Pascagoula	3/23/67	2.2	0	0	0	3	0
	(Bayou Cosette)	3/29/67	2.2	0	0	0	2	0
	Pascagoula	3/30/67	1.7	0	0	0	3	0
	(Jackson Co. Port Authority)	3/30/67	1.3	0	0	0	3	0
	Pascagoula	3/30/67	0	2	0	0	3	0
	(Bayou Cosette-Standard Oil)	3/30/67	0	2	0	0	3	0
	Pascagoula	3/31/67	0	2	0	0	3	0
	(Ingle Shipyard)	7/7-7/21/67			0 (total)	0	3 (total)	0
	East St. Louis	6/12-6/25/69			4 (total)	0	3 (total)	0
	Kansas City	6/27/69			0 (total)	0	0 (total)	0
	Butte	9/23/69			0	0	0	0
	(Basin Creek supply)	9/23/69			0 (total)	0	0 (total)	0
Mont:	Butte	9/23/69			0	0	0	0
	(Big Hole River supply)	9/23/69			0 (total)	0	0 (total)	0
	Butte	9/23/69			0	0	0	0
	(Moulton supply)	12/8-12/23/67			0	0	0	0
	Atlantic City	2/19/69			0	0	0	0
	Camden	6/6/69			0	0	4	0
N.J:	Hoboken	6/6/69			0	0	0	0
	Jersey City	2/26/69			0 (total)	0	5 (total)	0
	Trenton	7/6/69			0 (total)	0	4 (total)	0
	N. Mex: Albuquerque	7/6/69			0 (total)	0	8 (total)	0
	(Vol Andia well field 204)	7/6/69			0 (total)	0	4 (total)	0
	Albuquerque	7/10/69			0 (total)	0	4 (total)	0
N. Mex:	(San Jose well field 206)	7/6/69			0 (total)	0	4 (total)	0
	Albuquerque	7/10/69			0 (total)	0	4 (total)	0
	(Barton booster station 207)	7/10/69			5 (total)	0	11 (total)	0
	Albuquerque	7/10/69			3 (total)	0	7 (total)	0
	(Adriano booster station)	7/9/69			3 (total)	0	7 (total)	0
	Albuquerque	7/9/69			3 (total)	0	7 (total)	0
	(Griggs booster station 209)	7/9/69			3 (total)	0	7 (total)	0
	Albuquerque	7/9/69			0 (total)	0	3 (total)	0
	(Darman booster station 210)	7/9/69			0 (total)	0	3 (total)	0
	Croton	7/29/69			0 (total)	0	0 (total)	0
	Lynbrook	7/29-8/13/69			0 (total)	0	0 (total)	0
	New York	6/26-7/6/69			0 (total)	0	0 (total)	0
N.Y:	(East View)	6/26-7/6/69			0 (total)	0	0 (total)	0
	New York	6/26-7/6/69			0 (total)	0	0 (total)	0
	(North Castle)	6/26-7/6/69			0 (total)	0	4 (total)	0
	New York	7/13-7/30/69			0 (total)	0	3 (total)	0
	(Gramsville)	7/13-7/30/69			0 (total)	0	3 (total)	0
	New York	7/13-7/30/69			0 (total)	0	3 (total)	0
	(Croton watershed)	7/13-7/30/69			0 (total)	0	3 (total)	0
	New York	7/13-7/30/69			0 (total)	0	3 (total)	0

See footnote at end of table.

204

Radiological Health Data and Reports

Table 1. Radiological analyses of Interstate Carrier water supplies, 1967-1969—Continued

Sampling location	Sampling period	Total radium (pCi/liter)	Radium-226 (pCi/liter)	Strontium-90 (pCi/liter)	Gross alpha radioactivity (pCi/liter)		Gross beta radioactivity (pCi/liter)	
					Dissolved	Suspended	Dissolved	Suspended
N.Y. (continued)								
New York (Croton Lake Gate house)	7/15-7/20/69				0 (total)		0 (total)	
New York (Ashokan Reservoir)	6/25-7/1/69				0 (total)		0 (total)	
New York (Catskill Aqueduct, Pleasantville)	6/26-7/5/69				0 (total)		0 (total)	
Pennsylvania								
Fort Jefferson	5/29-6/5/69				0 (total)		0 (total)	
Richmond	9/3/69			0	0 (total)		29 (total)	
Richmond	4/23-5/6/69				0	0	4	0
Richmond	4/23-5/7/69				0	0	0	0
Richmond	10/25-11/5/67				0	0	0	0
Richmond	10/25/69				0	0	0	0
Richmond	7/6-7/22/69				0	0	0	0
N.C.								
Durham	6/25-6/28/69				0 (total)		0 (total)	
Graham	7/25-8/5/69				0	0	0	0
Ohio								
Akron	10/10-10/21/69				0	0	0	0
Ashtabula	5/4-5/17/67				0	0	0	0
Canton-Akron (Airport)	10/6-10/22/69				0	0	0	0
Cincinnati								
Cincinnati	3/3-3/10/69				0 (total)		0 (total)	
Cincinnati	5/2/69				0	0	4	0
Dayton	3/15-5/29/67				0	0	0	0
Fairport Harbor	5/14-5/22/67			0	0	0	45	0
Marion	11/12-11/27/69				0	0	4	0
Oregon	6/6-6/23/67				0	0	0	0
Portsmouth	11/14-11/29/69			0	0	0	20	0
Richmond	3/7-3/21/67			0	0	0	0	0
Vandalia	3/10/67				0	0	0	0
Wellsville	10/6-10/21/69				0	0	0	0
Youngstown	6/11/67				0	0	0	0
Ohio								
Alva	10/6/69				0	0	4	0
Lawton	10/21/69				0 (total)		3 (total)	
Tulsa	10/29/69				0 (total)		11 (total)	
Pa.								
Altoona	11/20/69				0 (total)		4 (total)	
Reading	3/21-3/31/69				0	0	0	0
Williamsport	6/21-6/23/69				0	0	0	0
R.C.								
Abbeville	2/21-2/24/67	0		0	0	0	0	0
Cayce	2/17-2/18/67	0		0	0	0	0	0
Charleston	6/5-6/16/69				0	0	0	0
Charleston	2/2/69				0	0	0	0
Columbia	2/5-2/15/69				0 (total)		0 (total)	
Flomona	8/4/69				0	0	2	0
Georgetown	2/20/69				0	0	0	0
Hartshorn	11/19/69				0	0	0	0
Tenn.								
Chattanooga	4/69				0	0	0	0
Johnson City	9/12/67	0		0	0	0	0	0
(Spring)	5/27/69				0	0	0	0
Johnson City	5/27/69				0	0	0	0
(Gray Station wells)					0	0	0	0
Kingsport	10/5-10/16/67	0		0				
Knoxville	4/9-4/22/69				0	0	0	0
Nashville	1/1-1/15/69				0	0	0	0
Tex.								
Amarillo	1/14/69				0	0	0	0
Amarillo	11/14/69				0 (total)		0 (total)	
Dallas	5/30/69				0 (total)		0 (total)	
Lubbock	6/3/69				0 (total)		0 (total)	
Lubbock	11/12/69				0 (total)		0 (total)	
Lubbock	11/12/69				0 (total)		0 (total)	
Midland	6/16/69				0 (total)		12 (total)	
Temple	5/12/69				0 (total)		0 (total)	
Wichita Falls	6/3/69				0 (total)		0 (total)	
W.Va.								
Northampton	7/5-7/22/69	0			0	0	0	0
Va.								
Norfolk	10/29-11/12/69				0 (total)	0	4 (total)	0
(McCree's Bridge purification plant)								
Norfolk	10/29-11/12/69				0	0	0	0
(Rich Co. purification plant)								
Portsmouth	11/5-11/19/69				0	0	0	0
W. Va.								
Charleston	3/15-3/1/69				0	0	4	0
Wisc.								
La Crosse	3/12-3/20/67				0 (total)		0 (total)	
Milwaukee	5/5-5/19/69				0	0	0	0
New Lisbon	5/12-5/28/67				0	0	0	0
Superior	5/17-5/31/67				0	0	0	0

* The minimum detectable radioactivity is 2 pCi/liter for strontium-90, alpha, and beta radioactivity; 0.1 pCi/liter for radium-226; and 1.0 pCi/liter for total radium. All values equal to or less than the minimum detectable radioactivity are reported as zero.

Table 2. Interstate carrier drinking water analysis program, 1967-1969 summary

Radioactivity	Number of samples	Concentrations* (pCi/liter)	
		Average	Range
Total radium.....	19	1.3	0-7.2
Radium-226.....	11	2.3	0-11.9
Radium-228.....	34	.1	0-3
Gross alpha:			
Detected.....	129	.4	0-38
Suspected.....	129	0	0-11
Total sample.....	64	.8	0-11
Gross beta:			
Detected.....	129	3.7	0-53
Suspected.....	129	.1	0-7
Total sample.....	64	4.0	0-53

* The minimum detectable radioactivity is 2 pCi/liter for strontium-90, alpha, and beta radioactivity; 0.1 pCi/liter for radium-226; and 1.0 pCi/liter for total radium. All values equal to or less than the minimum detectable radioactivity are reported as zero.

REFERENCES

- (1) DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE. PUBLIC HEALTH SERVICE. Federal Register Rules and Regulations, Title 42, Public Health Chapter 1, Part 72, Interstate Quarantine, Subpart J, Drinking Water Standards: 2154-2155 (March 6, 1962).
- (2) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Other coverage in *Radiological Health Data and Reports*:

Period	Issue
1961-1966	August 1968

Tritium in Community Water Supplies, 1969

*Bureau of Radiological Health
U.S. Public Health Service*

During 1969, a comprehensive survey of the quality of community water supplies in selected areas of the United States was conducted by the Bureau of Water Hygiene. Some of the water samples collected were sent to Bureau of Radiological Health laboratories for analysis of the radioactivity content, including tritium. Table 1 gives the results of tritium analyses as performed by the Northeastern, Southeastern, and Southwestern Radiological Health Laboratories.

The samples were collected by the grab sampling method on the date shown except where a range of dates indicates a composite of samples collected over that period of time. Due to the varying sensitivity of procedures used by the three laboratories, the minimum detectable concentration varies. Analytical values which are not statistically significant at the 2-sigma confidence level are reported as less than (<) a value corresponding to the approximate limit of detectability.

The significance of the concentrations of tritium observed in community water supplies may be evaluated using a relationship derived by Moghissi and Porter (1) from recommendations of the International Commission on Radiological Units

and Measurements. This relationship says that a dose equivalent of 0.17 mrem/a results from a tritium concentration in the body of 1 nCi/liter of water. Assuming that the concentration of tritium in all water taken into the body is equal to that found in the water supply, and that the specific activity of tritium in the body is essentially the same as that in the water supply, the radiation dose to the public may be estimated.

The highest concentration of tritium observed in the water supplies analyzed was 2.7 nCi/liter, corresponding to a dose of 0.47 mrem/a, or less than 0.3 percent of the Federal Radiation Council Radiation Protection Guide (RPG) of 170 mrem/a. The majority of water supplies analyzed had less than 1 nCi/liter of tritium, corresponding to a dose of less than 0.17 mrem/a or less than 0.1 percent of the RPG.

REFERENCE

- (1) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters in the United States, 1966. *Radiol Health Data Rep* 9:337-339 (1968).

Radiological Health Data and Reports

Table 1. Tritium in community water supplies, 1960

Location	Date collected (1960)	Sampled from	Type water	Source	Tritium concentration (nCi/liter)
Calif:					
Adelanto	2/19	Other	Finished	Ground	
Apple Valley	3/28	Well	Raw	Ground	8.4
Apple Valley	3/28	Well	Raw	Ground	8.4
Apple Valley	3/10	Well	Raw	Ground	8.4
Apple Valley	3/24	Well	Raw	Ground	8.4
Bythe	3/28	Well	Raw	Ground	8.4
Chico	3/28	Well	Raw	Ground	8.4
Chico	3/30-4/2	Reservoir	Finished	Ground	8.4
Chico	3/27	Well	Finished	Ground	8.4
Chico	3/30	Well	Raw	Ground	8.4
Colton	3/17	Dist. system	Finished	Other	8.4
Colton	3/30	Dist. system	Finished	Ground	8.4
Colton	3/18	Well	Finished	Ground	8.4
Colton	3/28	Well	Finished	Ground	8.4
East Highlands	3/17	Well	Raw	Ground	8.4
Hesperia	3/24	Well	Finished	Ground	8.4
Highland	3/18	Treatment plant	Finished	Ground	8.4
La Sierra	3/27	Well	Finished	Ground	8.4
La Sierra	3/27	Well	Finished	Ground	8.4
La Sierra	3/27	Well	Finished	Ground	8.4
Loma Linda	3/18-3/25	Dist. system	Finished	Ground	8.4
Loomis Valley	3/24	Dist. system	Finished	Ground	8.4
Loomis Valley	3/25	Well	Finished	Ground	8.4
Needles	3/31	Well	Raw	Ground	1.4 ± .4
Parker Dam	3/24	Well	Raw	Ground	1.5 ± .4
Rialto	3/28	Well	Raw	Ground	8.4
San Bernardino	3/28	Dist. system	Finished	Ground	8.4
San Bernardino	3/19	Well	Finished	Ground	8.4
San Bernardino	3/17	Well	Raw	Ground	8.4
San Bernardino	3/19	Reservoir	Finished	Ground	8.4
Victorville	3/27	Well	Raw	Ground	8.4
Victorville	3/27	Well	Raw	Ground	8.4
Calo:					
Beulah	6/17	Treatment plant	Finished	Surface	1.1 ± .2
Pueblo	6/13-6/26	Treatment plant	Finished	Surface	2.0 ± .2
Pueblo	6/18	Well	Finished	Ground	8.4
Conn:					
Greenwich	6/4-6/10	Treatment plant	Finished	Surface	1.4 ± .7
Ga:					
Senoia	7/9	Well	Raw	Ground	8.4
Taylorville	7/10	Well	Raw	Ground	8.4
State City	8/4	Well	Raw	Ground	8.4
Cartersville	8/5	Well	Raw	Ground	8.4
Ind:					
Lawrenceburg	3/5-3/18	Treatment plant	Finished	Ground	1.4 ± .6
Kans:					
Oardner	6/4-6/18	Treatment plant	Finished	Surface	8.4
Olathe	6/11-6/24	Treatment plant	Finished	Ground	8.4
Olathe	6/17	Treatment plant	Finished	Surface	4 ± .4
Spring Hill	6/4-6/17	Treatment plant	Finished	Surface	7 ± .4
La:					
Gretna	6/16-6/20	Treatment plant	Finished	Surface	4 ± .1
New Orleans	6/20	Reservoir	Finished	Ground	8.4
Chalmers	6/19-7/2	Treatment plant	Finished	Surface	3 ± .3
Westwego	6/17-6/30	Treatment plant	Finished	Surface	5 ± .5
Mo:					
Cleveland	6/5-6/18	Treatment plant	Finished	Surface	8.4
Harrisonville	6/5-6/19	Treatment plant	Finished	Surface	8.4
Kansas City	6/12-6/25	Treatment plant	Finished	Surface	1.3 ± .4
Pleasant Hill	6/6-6/20	Treatment plant	Finished	Surface	9 ± .4
Raymore	6/5-6/19	Treatment plant	Finished	Surface	6 ± .4
Smithville	6/12-6/26	Treatment plant	Finished	Surface	8.4
N.Y:					
Bathpage	7/14-7/28/60	Treatment plant	Finished	Ground	8.4
Blauvelt	5/2/60	Well	Raw	Ground	<1.0
Brentwood	6/4/60	Well	Raw	Ground	<1.0
Calverton	6/25/60	Well	Finished	Ground	<1.0
Camp Ramapo (Pomona)	7/10/60	Well	Raw	Ground	1.0
Cove Neck	7/1/60	Well	Raw	Ground	9 ± .7
Germville	6/5/60	Well	Finished	Ground	<1.0
Golden Bridge	5/28/60	Well	Finished	Ground	<1.0
Huntington	5/18/60	Dist. system	Raw	Ground	<1.0
Jamestown	9/10/60	Treatment plant	Partly treated	Ground	<1.0
Jericho	7/14/60	Well	Raw	Ground	<1.0
Levittown	7/15/60	Treatment plant	Finished	Ground	<1.0
Litchfield	7/16/60	Dist. system	Finished	Ground	<1.0
Manhasset	7/25/60	Dist. system	Finished	Ground	<1.0
Manhasset	7/26/60	Dist. system	Finished	Ground	<1.0
Merrick	7/30/60	Well	Raw	Ground	<1.0
Minerva Village	7/31/60	Well	Raw	Ground	8.4
Montauk	8/24/60	Well	Raw	Ground	<1.0

See footnote at end of table.

Table 1. Tritium in community water supplies, 1969—Continued

Location	Date Collected (1969)	Sampled from	Type water	Source	Tritium concentration (mCi/liter)
N.Y. (continued)					
Green Bay Park	5/25/69	Treatment plant	Finished	Ground	<1.0
Green Bay Park	5/25/69	Well	Other	Ground	<1.0
Green Bay Park	5/25/69	Treatment plant	Finished	Ground	.7 ± .6
Port Jefferson	7/15/69	Well	Raw	Ground	<1.0
San Onofre	4/25/69	Treatment plant	Finished	Ground	<1.0
San Onofre	4/25/69	Treatment plant	Finished	Combined	<1.0
Shoreham	4/20/69	Dist. system	Finished	Surface	<1.0
Shoreham	4/20/69	Dist. system	Finished	Ground	<1.0
Shoreham	4/20/69	Dist. system	Finished	Ground	<1.0
Spring Valley	5/15/69	Well	Other	Ground	<1.0
Spring Valley	5/15/69	Dist. system	Finished	Combined	.7 ± .6
Spring Valley	5/15/69	Well	Raw	Ground	<1.0
Wading River	7/14/69	Treatment plant	Finished	Ground	.7 ± .6
Wading River	7/14/69	Well	Raw	Ground	.7 ± .6
Wading River	7/14/69	Well	Raw	Ground	.7 ± .6
Ohio					
Adrian	2/7/69	Dist. system	Finished	Ground	<1.0
Adrian	2/26-3/17	Treatment plant	Finished	Ground	<1.0
Adrian	2/26-3/17	Dist. system	Finished	Ground	1.1 ± .9
Adrian	2/26-3/17	Well	Finished	Ground	1.1 ± .9
S.C.					
Goose Creek	3/3	Dist. system	Finished	Ground	<1.0
Goose Creek	3/4	Dist. system	Other	Ground	<1.0
Goose Creek	3/4	Well	Other	Ground	.3 ± .1
Goose Creek	3/4	Dist. system	Other	Ground	.3 ± .1
Goose Creek	3/4	Well	Other	Ground	.3 ± .1
Vt.					
Acushnet	9/2	Dist. system	Partly treated	Combined	<1.0
Acushnet	7/15	Dist. system	Finished	Surface	<1.0
Acushnet	7/15-7/26	Reservoir	Finished	Combined	1.3 ± .9
Acushnet	7/23	Dist. system	Finished	Ground	2.1 ± .9
Acushnet	7/23	Dist. system	Raw	Ground	1.5 ± .6
Acushnet	7/30	Dist. system	Raw	Ground	<1.0
Acushnet	7/30	Treatment plant	Finished	Surface	<1.0
Acushnet	8/20	Dist. system	Finished	Ground	2.7 ± .6
Acushnet	8/21	Well	Raw	Ground	<1.0
Acushnet	8/21	Dist. system	Finished	Ground	2.1 ± .6
Acushnet	8/21	Reservoir	Raw	Ground	1.3 ± .9
Acushnet	8/21	Dist. system	Finished	Ground	1.3 ± .9
Acushnet	8/21	Treatment plant	Finished	Surface	2.1 ± .7
Acushnet	8/21	Other	Raw	Surface	1.6 ± .7
Acushnet	8/21	Other	Finished	Surface	1.9 ± .7
Acushnet	7/10	Treatment plant	Finished	Surface	<1.0
Acushnet	7/10	Dist. system	Finished	Ground	1.5 ± .9
Acushnet	7/10	Dist. system	Finished	Surface	1.8 ± .9
Acushnet	7/14	Other	Raw	Ground	1.8 ± .9
Acushnet	7/26	Dist. system	Finished	Surface	1.8 ± .9
Acushnet	8/6	Dist. system	Finished	Surface	1.4 ± .9
Acushnet	7/13	Dist. system	Finished	Surface	<1.0
Acushnet	9/17	Dist. system	Other	Ground	<1.0
Acushnet	9/19	Other	Partly treated	Surface	1.5 ± .7
Acushnet	7/17	Well	Finished	Ground	2.1 ± .6
Acushnet	8/18	Dist. system	Raw	Ground	1.8 ± .9
Acushnet	7/17	Dist. system	Finished	Surface	1.6 ± .6
Acushnet	7/20	Dist. system	Other	Ground	1.8 ± .7
Acushnet	7/9	Other	Raw	Combined	<1.0
Acushnet	7/20	Dist. system	Finished	Ground	1.7 ± .6
Acushnet	8/20	Dist. system	Finished	Ground	1.4 ± .6
Acushnet	8/20	Dist. system	Raw	Surface	<1.0
Acushnet	7/10	Treatment plant	Finished	Surface	1.3 ± .6
Acushnet	8/9	Dist. system	Finished	Ground	1.3 ± .7
Acushnet	7/24	Dist. system	Finished	Ground	1.7 ± .6
Acushnet	8/19	Dist. system	Finished	Ground	<1.0
Acushnet	8/23	Reservoir	Raw	Ground	1.3 ± .6
Acushnet	8/23	Other	Raw	Ground	<1.0
Acushnet	8/21	Other	Finished	Ground	<1.0
Acushnet	8/28	Dist. system	Finished	Ground	2.0 ± .6
Acushnet	8/18	Dist. system	Finished	Ground	<1.0
Acushnet	8/4	Dist. system	Finished	Ground	<1.0
W. Va.					
Corbin	2/18	Treatment plant	Finished	Surface	.3 ± .1
Corbin	2/28-3/1	Treatment plant	Finished	Ground	.3 ± .1
Corbin	2/28-3/1	Treatment plant	Finished	Surface	.3 ± .1
Corbin	2/28-3/1	Treatment plant	Finished	Surface	.3 ± .1
Corbin	2/28-3/1	Treatment plant	Finished	Ground	.3 ± .1
Corbin	2/28-3/1	Treatment plant	Finished	Ground	.3 ± .1
Corbin	2/28-3/1	Treatment plant	Finished	Surface	.3 ± .1
Corbin	2/28-3/1	Treatment plant	Finished	Surface	.3 ± .1

* Two-sigma error.

* These samples were not part of this study, but were collected in a related survey on rural water.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically

to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*.

<u>Network</u>	<u>Period</u>	<u>Issue</u>
Fallout in the United States and Other Areas, <i>HASL</i>	January-June 1968	October 1969
Plutonium in Airborne Particulates and Precipitation, <i>PHS</i>	April-December 1969	October 1970

1. Radiation Alert Network **August 1970**

*National Air Pollution Control Administration
U.S. Public Health Service*

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Most of the stations are operated by State Health Department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter

products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate National Air Pollution Control Administration officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Division of Air Quality And Emission Data, NAPCA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during August 1970. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.

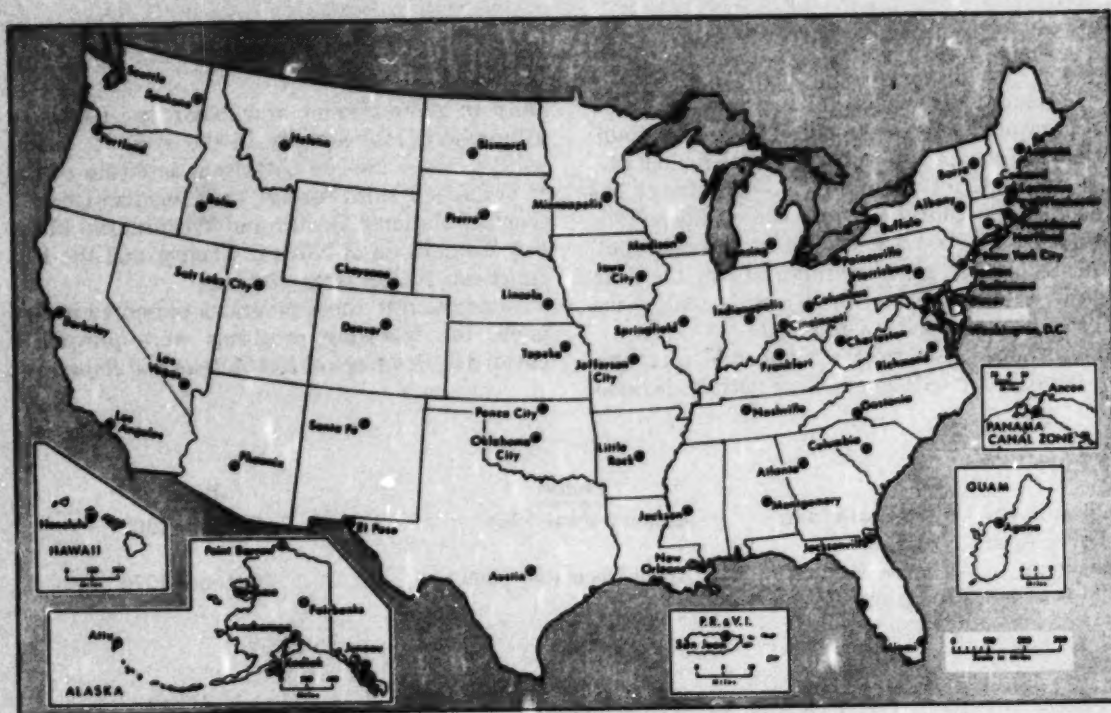


Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, August 1970

Station location	Number of samples	Air surveillance			Last profile in RHD&R	Number of samples	Precipitation			
		Gross beta radioactivity ($\mu\text{Ci}/\text{m}^3$)					Total depth sample (mm)	Field estimation of deposition		
		Maximum	Minimum	Average ^a				Number of samples	Depth (mm)	Total deposition ($\mu\text{Ci}/\text{m}^2$)
Ala: Montgomery	31	3	0	1	Oct 70	(a) 6	153	6	153	40
Alaska: Anchorage	13	0	0	0	June 70					
Alaska: Attu Island	30	0	0	0	Nov 70					
Alaska: Fairbanks	18	1	0	1	July 70					
Alaska: Juneau	7	3	0	4	Aug 70					
Alaska: Kodiak	(a) 7				Sept 70					
Alaska: Nome	(a) 7				Dec 70	(a) 6	103	6	103	
Alaska: Point Barrow	(a) 7				Dec 70	(a) 6				
Alaska: Phoenix	11	4	1	2	Aug 70	(a) 6				
Ark: Little Rock	12	4	0	1	June 70	(a) 6				
Calif: Berkeley	31	0	0	0	Sept 70	(a) 6				
Calif: Los Angeles	31	3	0	1	Mar 70	(a) 6				
C.E.: Anson	17	0	0	0	Sept 70	(a) 6				
Colo: Denver	20	7	1	4	Sept 70	3	10	(a) 6	60	
Conn: Hartford	21	2	0	1	July 70	(a) 6	66	6	66	
Del: Dover	25	2	0	1	May 70	(a) 6				
D.C.: Washington	25	1	0	0	Dec 70	(a) 6				
Fla: Jacksonville	21	1	0	0	June 70	11	223	5	125	40
Fla: Miami	13	0	0	0	July 70	6	106	6	106	
Ga: Atlanta	20	3	1	1	Apr 70	1	31	1	31	15
Guam: Agaña	(a) 20				May 70	(a) 1				
Hawaii: Honolulu	25	0	0	0	Nov 70	2	10	(a) 6		
Idaho: Boise	12	4	1	2	Nov 70	(a) 6				
Idaho: Springfield	(a) 12				Dec 70	(a) 6				
Ill: Indianapolis	(a) 15				Apr 70	(a) 6				
Iowa: Iowa City	21	5	1	2	Sept 70	4	56	4	56	1
Kans: Topeka	21	5	1	3	June 70	5	36	5	36	1
Ky: Frankfort	10	5	2	3	Dec 70	(a) 4				
La: New Orleans	18	1	0	0	Aug 70	9	316	(a) 6		
Maine: Augusta	20	3	0	2	Feb 70	3	63	3	63	0
Md: Baltimore	21	2	0	1	Aug 70	6	36	6	36	1
Mass: Lawrence	21	2	0	1	Sept 70	6	99	6	99	0
Mass: Worcester	20	3	0	1	Oct 70	6	104	6	104	0
Mich: Lansing	19	5	0	2	Nov 70	4	59	4	59	4
Miss: Minneapolis	21	3	0	2	May 70	5	80	4	80	4
Miss: Jackson	14	2	0	1	Aug 70	4	108	4	108	19
Mo: Jefferson City	20	8	1	2	Apr 70	6	77	6	77	0
Mont: Helena	17	7	0	1	Oct 70	3	18	3	18	0
Nebr: Lincoln	14	2	1	4	Apr 70	2	21	2	21	3
Nev: Las Vegas	18	3	1	2	July 70	(a) 2				
N.H.: Concord	(a) 21				Dec 70	(a) 6				
N.J.: Trenton	21	2	0	1	Aug 70	5	110	5	110	4
N. Mex: Santa Fe	21	2	1	1	Oct 70	8	52	8	52	0
N.Y.: Albany	13	2	0	1	Apr 70	6	63	6	63	23
N.Y.: Buffalo	21	2	0	1	Sept 70	(a) 6				
N.Y.: New York City	(a) 21				Oct 70	(a) 6				
N.C.: Gastonia	16	9	1	4	Sept 70	5	99	(a) 3		
N. Dak: Bismarck	21	5	0	2	Dec 70	2	4	2	4	1
Ohio: Cincinnati	(a) 4				May 70	(a) 2				
Ohio: Columbus	20	3	1	2	Aug 70	(a) 4				
Ohio: Painesville	21	5	1	3	July 70	4	51	4	51	9
Okla: Oklahoma City	21	6	1	3	Nov 70	2	17	1	17	1
Okla: Ponca City	21	5	1	3	July 70	5	40	5	40	0
Oreg: Portland	18	2	0	1	Apr 70	(a) 3	48	3	48	10
Pa: Harrisburg	14	3	0	1	Apr 70	(a) 3	48	3	48	10
P.R.: San Juan	(a) 19				Aug 70	(a) 1	30	1	30	2
R.I.: Providence	14	1	0	1	Nov 70	3	49	3	49	0
S.C.: Columbia	8	6	1	3	Oct 70	(a) 3				
S. Dak: Pierre	20	3	0	1	Aug 70	(a) 6	104	6	104	3
Tenn: Nashville	13	11	2	4	Nov 70	(a) 6				
Tex: Austin	(a) 21				May 70	(a) 6				
Utah: El Paso	31	3	1	1	Dec 70	(a) 1	7	1	7	0
Utah: Salt Lake City	19	6	0	3	Mar 70	6	71	6	71	11
Vt: Barre	21	2	0	1	June 70	3	94	3	94	28
Va: Richmond	21	1	0	0	June 70	2	16	(a) 3		
Wash: Seattle	21	3	1	2	May 70	(a) 3				
W. Va: Charleston	21	3	0	2	Oct 70	8	90	8	90	17
Wis: Madison	21	7	0	3	June 70	3	9	3	9	3
Wyo: Cheyenne	21	7	1	3	July 70	(a) 3				
Network summary	1,009	11	0	2		104	83	4	62	8

^a The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.^b No report received. (Air samples received without field estimate data are not considered by the data program.)^c No precipitation sample collected.^d This station is part of the plutonium in precipitation network. No gross beta measurements are done.^e Samples were collected but no field estimates were received.

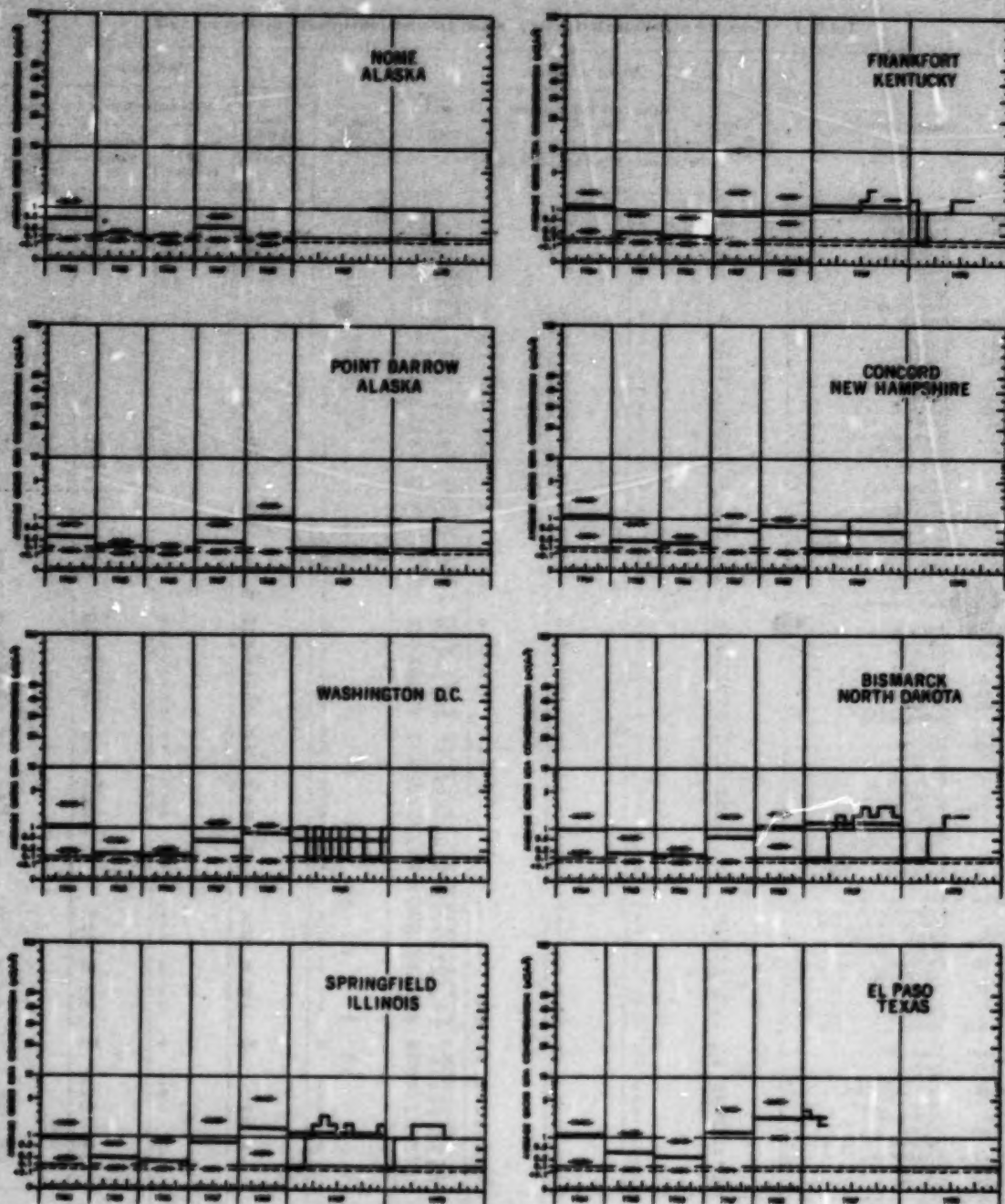


Figure 2. Monthly and yearly profile of beta radioactivity in air—Radiation Alert Network, 1964–August 1970

2. Canadian Air and Precipitation Monitoring Program,¹ August 1970

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (1-5).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports*.

¹ Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for August 1970 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, August 1970

Station	Number of samples	Air surveillance, gross beta radioactivity (pCi/m ³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (uCi/m ²)
Calgary	0	NS	NS	NS	287	2.6
Coral Harbour	25	0.5	0.0	0.2	122	9.8
Edmonton	30	.5	.0	.3	131	6.0
Ft. Churchill	11	.3	.0	.1	106	7.0
Fredericton	5	.3	.1	.3	NS	NS
Goose Bay	5	.3	.1	.3	49	5.3
Halifax	5	.3	.1	.3	55	6.1
Inuvik	5	.1	.0	.1	66	3.6
Montreal	30	.5	.0	.3	38	3.9
Moosonee	5	.6	.0	.3	43	3.3
Ottawa	31	.6	.1	.3	18	1.3
Quebec	25	.5	.1	.3	84	5.3
Regina	5	.3	.1	.2	177	3.2
Resolute	5	.1	.0	.1	31	1.0
St. John's, Nfld.	5	.3	.1	.1	24	7.9
Saskatoon	5	.3	.1	.2	180	4.8
Sault Ste. Marie	5	.4	.2	.2	83	4.5
Thunder Bay	31	.6	.1	.3	95	5.9
Toronto	31	.7	.1	.3	84	8.1
Vancouver	5	.3	.1	.1	248	1.4
Whitehorse	31	.3	.0	.1	NS	NS
Windsor	31	.6	.1	.3	49	1.0
Winnipeg	3	.3	.1	.1	74	5.5
Yellowknife	31	.4	.0	.1	25	2.2
Network summary	265	0.7	0.0	0.2	98	4.2

NS, no sample.



Figure 3. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program August 1970

*Pan American Health Organization and
U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 4. Analytical techniques were described in the January 1968 issue of *Radiological Health Data and Reports*. The August 1970 air monitoring results from the participating countries are given in table 3.



Figure 4. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, August 1970

Station location	Number of samples	Gross beta radioactivity (pCi/m ³)		
		Maximum	Minimum	Average
Argentina: Buenos Aires	13	0.25	0	0.08
Bolivia: La Paz	21	0.30	.17	0.06
Chile: Santiago	24	2.37	.09	.53
Colombia: Bogota	19	.28	.02	.11
Ecuador: Cuenca	NS	NS	NS	NS
Ecuador: Guayaquil	16	2.48	.02	.71
Ecuador: Quito	NS	NS	NS	NS
Guyana: Georgetown	6	.02	.02	.19
Jamaica: Kingston	NS	NS	NS	NS
Peru: Lima	26	7.71	.49	1.73
Venezuela: Caracas	13	.21	.05	.12
West Indies: Trinidad	NS	NS	NS	NS
Pan American summary	137	8.33	0	1.01

* The monthly average is calculated by weighting the individual sample with length of sampling period. Reported values of less than 0.005 pCi/m³ are considered as 0.00 pCi/m³ in averaging.
NS, no sample.

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- (4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).
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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here

are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety

in directives published in the "AEC Manual."¹

Summaries of the environmental radioactivity data follow for Mound Laboratory, Savannah River Plant, and S1C Prototype Reactor Facility.

¹Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0534 of the AEC Manual.

1. Mound Laboratory¹ July-December 1969

*Monsanto Research Corporation
Miamisburg, Ohio*

The environmental monitoring program for Mound Laboratory is planned and coordinated with all of the projects conducted at the laboratory. Air and water monitoring in the uncontrolled environs surrounding the laboratory is specified for the radionuclides which could be released to the environment. Only polonium-210, plutonium-238, and hydrogen-3 (tritium) are potential environmental contaminants.

Air monitoring

Mobile air monitoring equipment, mounted on a 1-ton panel truck, for measurement of tritium and collection of particulate alpha-particle emitters, was used in the routine monitoring of environmental air within a radius of 20 miles from the laboratory during the collection period. Since the sampling zone is dependent on the wind direction it is possible that air samples from all zones will not be collected during the reporting period.

Airborne polonium and plutonium particulates are collected on filter paper with a high-volume air sampler. One-fourth of each filter paper is processed and analyzed for polonium. The remaining three-fourths of each filter paper is processed and analyzed for plutonium.

Airborne tritium is monitored by bubbling air through a liquid scintillation counting solution with p-dioxane as the organic solvent. The counting solution is counted directly in a liquid spectrometer.

¹Summarized from "Environmental Monitoring Report: July-December 1969 and 1969 Summary" (MLM-1616).

The results of the airborne monitoring program are presented in tables 1, 2, and 3. The average concentrations of plutonium, polonium, and tritium in the environment are below the AEC radiation protection standards.

Table 1. Atmospheric monitoring of polonium-210 Mound Laboratory environs, July-December 1969

Range (miles)	Number of samples	Concentration* (fCi/m ³)		Average as percent of AEC standard ^b
		Maximum	Average	
0-3 (upwind)-----	13	22.8	14.5	0.07
0-3 (downwind)-----	14	15.6	5.7	.04
3-5 (downwind)-----	14	25.8	14.5	.07
5-10 (downwind)-----	14	84.9	17.8	.09
10-15 (downwind)-----	14	28.0	13.0	.06
15-30 (downwind)-----	13	14.4	6.8	.03

* Lowest detectable level (LDL) for polonium-210 in air is 8.0 fCi/m³ for samples collected 0-3 miles upwind, 3-5 miles downwind, 5-10 miles downwind, and 10-15 miles downwind. The LDL is 5.3 fCi/m³ for samples collected 0-3 miles downwind and 15-30 miles downwind. All values which were not detectable were set equal to these values when average values were calculated.

^b The applicable AEC radiation protection standard for polonium-210 in air is 30 fCi/m³.

Table 2. Atmospheric monitoring of plutonium-238 Mound Laboratory environs, July-December 1969

Range (miles)	Number of samples	Concentration* (fCi/m ³)		Average as percent of AEC standard ^b
		Maximum	Average	
0-3 (upwind)-----	13	19.7	6.1	0.01
0-3 (downwind)-----	14	19.3	6.2	.02
3-5 (downwind)-----	14	15.2	8.0	.80
5-10 (downwind)-----	14	16.0	9.1	.91
10-15 (downwind)-----	14	19.7	7.5	.75
15-30 (downwind)-----	13	19.3	8.5	.85

* Lowest detectable level (LDL) for plutonium-238 in air is 1.3 fCi/m³ for samples collected 0-3 miles upwind, 3-5 miles downwind, 5-10 miles downwind, and 10-15 miles downwind. The LDL is 0.9 fCi/m³ for samples collected 0-3 miles downwind and 15-30 miles downwind. All values which were not detectable were set equal to these values when average values were calculated.

^b The applicable AEC radiation protection standard for plutonium-238 in air is 1 fCi/m³.

Table 3. Atmospheric monitoring of tritium, Mound Laboratory environs, July-December 1969

Range (miles)	Number of samples	Concentration* (nCi/m ³)		Average as percent of AEC standard ^b
		Maximum	Average	
0-3 (upwind)-----	12	5.48	1.51	0.75
0-3 (downwind)-----	12	1.00	1.00	.50
3-5 (downwind)-----	11	3.99	1.38	.62
5-10 (downwind)-----	11	2.39	1.13	.56
10-15 (downwind)-----	11	1.51	1.06	.53
15-30 (downwind)-----	11	1.51	1.06	.53

* Lowest detectable limit for tritium in air is 1.00 nCi/m³. All values which were not detectable were set equal to this value when average values were calculated.

^b The applicable AEC radiation protection standard for tritium in air is 300 nCi/m³.

Water monitoring

Liquid radioactive waste materials from polonium and plutonium operations at the laboratory are processed separately to reduce the concentrations of these radionuclides to a level at which they may be discharged to the environment. Treated polonium liquid waste is discharged to the Great Miami River via a closed sewer line which also carries the treated plant sewage. The treated plutonium waste is discharged to a drainage ditch which runs through the plant site and eventually reaches the river.

Helium-3 being purified at the Mound Laboratory contains small quantities of tritium. In addition, tritium is recovered from various AEC tritium-contaminated wastes. Liquid waste generated by these operations is treated (diluted with water when necessary) and discharged to the same drainage ditch as plutonium waste. Some tritium-

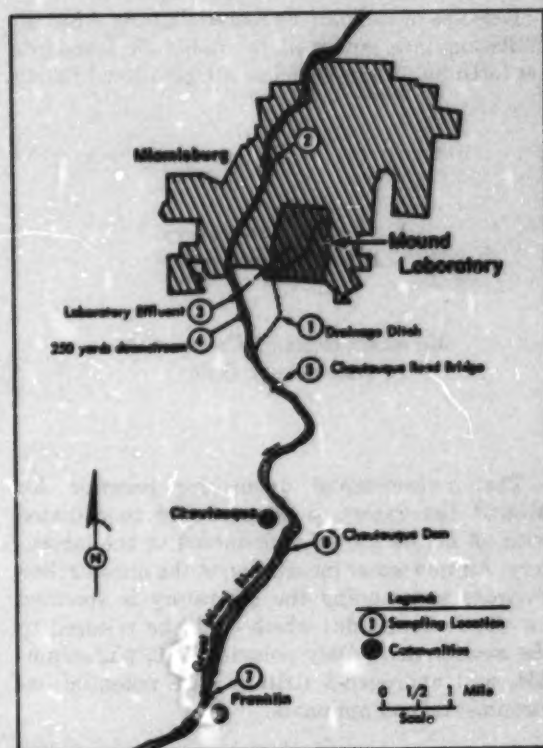


Figure 1. Water sampling locations, Mound Laboratory

Table 4. Offsite water monitoring for radioactivity, Mound Laboratory environs, July-December 1969

Radionuclide and sampling locations ^a	Number of samples	Concentration	
		Maximum	Average ^b
Polonium-210:^c (pCi/liter)			
1 (Drainage ditch).....	23	2.70	1.84
2 (Upstream from laboratory).....	23	1.80	1.80
3 (Laboratory effluent).....	22	768	114
4 (250-yards downstream).....	22	57.7	6.84
5 (Chautauqua Road Bridge).....	22	1.80	1.80
6 (Chautauqua Dam).....	22	1.80	1.80
7 (Franklin, Ohio).....	21	1.80	1.80
8 (Pond, opposite V.A. hospital, Dayton, Ohio, 8 miles NE of Mound Laboratory).....	23	1.80	1.80
9 (Pond, Possum Creek Reserve, Dayton, Ohio, 6 miles NE of Mound Laboratory).....	23	1.80	1.80
Plutonium-238:^c (pCi/liter)			
1 (Drainage ditch).....	23	40.6	12.3
2 (Upstream from laboratory).....	23	11.3	5.32
3 (Laboratory effluent).....	22	314	23.9
4 (250-yards downstream).....	22	5.71	5.38
5 (Chautauqua Road Bridge).....	22	11.3	5.73
6 (Chautauqua Dam).....	21	10.4	5.30
7 (Franklin, Ohio).....	21	10.2	5.00
8 (Pond, opposite V.A. Hospital, Dayton, Ohio, 8 miles NE of Mound Laboratory).....	23	7.06	4.81
9 (Pond, Possum Creek Reserve, Dayton, Ohio, 6 miles NE of Mound Laboratory).....	24	95.7	9.14
Tritium (hydrogen-3):^c (pCi/liter)			
1 (Drainage ditch).....	23	14.7	1.11
2 (Upstream from Laboratory).....	22	.17	.06
3 (Laboratory effluent).....	21	.63	.19
4 (250-yards downstream).....	21	.40	.07
5 (Chautauqua Road Bridge).....	21	.34	.07
6 (Chautauqua Dam).....	20	.46	.07
7 (Franklin, Ohio).....	20	.42	.07
8 (Pond, opposite V.A. Hospital, Dayton, Ohio, 8 miles NE of Mound Laboratory).....	22	.43	.07
9 (Pond, Possum Creek Reserve, Dayton, Ohio, 6 miles NE of Mound Laboratory).....	22	.30	.07

^a See figure 1 for number of sampling locations.

^b The applicable AEC radiation protection standards for uncontrolled areas are as follows:

Polonium-210 in water: 700 pCi/liter

Plutonium-238 in water: 5 nCi/liter

Tritium in water: 3 pCi/liter

^c Minimum detectable level for polonium-210 in water is 1.80 pCi/liter.

Minimum detectable level for plutonium-238 in water is 4.5 pCi/liter.

Minimum detectable level for tritium in water is 50 nCi/liter.

All samples which were not detectable were set equal to their respective minimum detectable level when average values were calculated.

contaminated liquid wastes are discharged to the same closed sewer line as polonium.

Water samples are collected weekly from the Great Miami River, the drainage ditch, and two ponds northeast of Mound Laboratory (figure 1). The average concentrations of plutonium and tritium in water discharged to the environment were well below the AEC radiation protection

standards. Average concentrations of tritium, polonium-210, and plutonium-238 are given in table 4 for July-December 1969.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
July-December 1969	December 1969
January-June 1969	June 1970

2. Savannah River Plant¹ July-December 1969

E. I. duPont de Nemours
Aiken, S.C.

The Savannah River Plant (SRP), built and operated for the Atomic Energy Commission by E. I. du Pont de Nemours and Company, occupies an area of 312 square miles along the Savannah River, 22 miles downstream from Augusta, Ga. Production facilities include a fuel preparation area, three reactors, two fuel separation areas, and a heavy water production plant. A basic goal in plant operation is total containment of radioactive waste. Although some very low level gaseous and liquid wastes are discharged to the environment in controlled releases, dispersal is adequate to ensure environmental concentrations below recommended guides.

A continuous monitoring program has been maintained since 1951 (before plant startup) to determine the concentrations of radioactive materials in a 1,200 square mile area outside the plant. Included in this area are parts of Aiken, Barnwell, and Allendale Counties in South Carolina, and Richmond, Burke, and Screven Counties in Georgia. This surveillance determines the magnitude and origin of any radioactivity above natural levels. Measured concentrations of radionuclides in air, water, and milk are compared with the AEC radiation protection standards as given in the AEC Manual.

Sensitive instruments, which can detect traces of radioactive materials far below concentrations of hazard significance, are used to determine radioactivity in the environs. Plant-released radioactivity and atmospheric fallout are included in the reported concentrations. Maximum and minimum values given are for individual samples collected during the report period.

Atmospheric monitoring

Concentrations of radioactive materials in the atmosphere were measured by biweekly analyses

¹ Summarized from "Effect of the Savannah River Plant on Environmental Radioactivity, Semiannual Report, July-December 1969 (DPST-10-30-1).

of air filters collected at five monitoring stations near the plant perimeter and 10 stations around a circle of about a 25-mile radius from the center of the plant (figure 2). Deposition rates of radio-

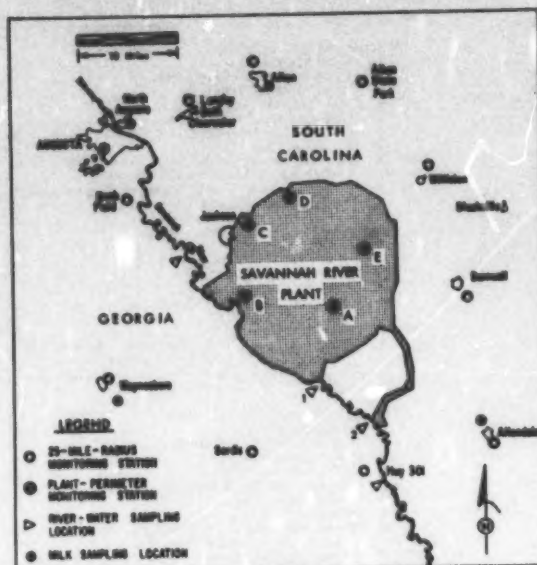


Figure 2. Environmental sampling locations Savannah River Plant

active material at each station were also determined by monthly analyses of rainwater ion exchange columns (fallout collectors). The monitoring stations are spaced so that a significant release of airborne radioactivity by SRP would be detected regardless of the prevailing wind. All stations operate continuously. Four additional air monitoring stations at Savannah and Macon, Ga., and at Columbia and Greenville, S.C., are so distant from SRP that the effect of SRP operations is negligible; they serve as reference points for determining background radioactivity levels (figure 3). This system permits comprehensive surveillance of atmospheric radioactivity and also makes it possible to differentiate between fallout and SRP releases.

The small amount of filterable beta radioactivity released to the atmosphere, primarily from the fuel separation areas, was obscured by fallout. The influence of nuclear tests, which resumed in September 1961, is shown in figure 4. The present low levels of atmospheric activity are attributed to the moratorium on above-ground nuclear tests.

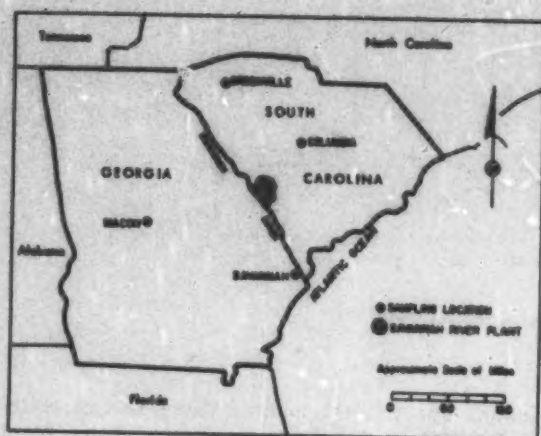


Figure 3. Distant air monitoring stations Savannah River Plant

The observed spring increases are anticipated and result primarily from the mixing of the stratospheric debris into the troposphere. The average beta concentration in air (0.15 pCi/m^3) was about the same as the previous 6 months and was two-

fold higher than the same period of 1968. Gamma-emitting radionuclides in fallout were cesium-134-137, cerium-141-144, ruthenium-103-106, and zirconium-niobium-95.

Short radioactive half-life barium-lanthanum-140, neptunium-239, and iodine-131 in routine air samples were less than the level of detection throughout the period. The major component, beryllium-7, is a naturally occurring radionuclide formed by interaction of cosmic rays with oxygen and nitrogen in the upper atmosphere. Radioactivity in air, determined from filter analyses, is shown in table 5. The July-December 1969 concentrations of filterable beta radioactivity (0.15 pCi/m^3) and alpha radioactivity (0.7 fCi/m^3) in air were 0.15 and 1.0 percent of the respective AEC standards. Tritium oxide concentrations in air, at the plant perimeter and at the 25-mile stations, did not exceed 0.2 percent of the AEC standard.

Deposition of fallout during July-December 1969 averaged 7 nCi/m^2 at the plant perimeter locations and 8 nCi/m^2 at 25-mile radius locations; comparable values for the last half of 1969 were

Table 5. Radioactivity in air, Savannah River Plant, July-December 1969

Sampling points	Alpha radioactivity ^a (fCi/m ³)			Nonvolatile beta radio- activity ^b (pCi/m ³)			Specific radionuclides in composite samples (pCi/m ³)					
	Maximum	Minimum	Average	Maximum	Minimum	Average	³ H, ³ H ₂ O	⁷⁰ Se	¹³⁷ Cs	¹⁴⁰ La	¹⁴⁰ Ba	⁹⁰ Y
Plant perimeter:												
A	1.8	ND	0.8	0.49	0.06	0.17						
B	1.3	.4	.7	.52	.06	.21						
C	1.4	ND	.8	.35	.06	.16	0.000	0.01	0.04	0.06	0.08	0.14
D	1.1	ND	.6	.34	.06	.15						
E	1.1	ND	.5	.33	.06	.15						
Average			0.6			0.17						
25-mile-radius:												
Aiken Airport	1.6	ND	.6	.33	ND	.14						
Aiken State Park	1.1	ND	.6	.33	.05	.14						
Allendale	.9	ND	.5	.30	.04	.14						
Barnwell	1.1	ND	.6	.30	.06	.14						
Bush Field	.6	.3	.5	.32	.02	.12	.000	.01	.04	.04	.08	.14
Langley	4.9	.4	1.0	.32	.05	.14						
Hardin	1.1	ND	.5	.30	.04	.14						
Waynesboro	1.3	.3	.6	.31	.06	.14						
Wilmington	2.5	ND	1.1	.40	.04	.14						
Highway 301	2.3	ND	.6	.30	.06	.17						
Average			0.7			0.14						
Distant air-monitoring:												
S.C. Columbia	2.3	ND	1.0	.51	ND	.15						
Greenville	1.7	.3	.9	.41	.06	.17						
Ga. Macon	1.4	ND	.7	.35	.04	.13	.000	.01	.04	.04	.08	.13
Savannah	1.4	ND	.6	.29	.06	.16						
Average			0.8			0.15						

^a AEC radiation protection standard—70 fCi/m³.

^b AEC radiation protection standard—100 pCi/m³.

^c The beryllium-7 concentrations reported for the January-June 1969 were incorrect. The corrected concentration range is 0.11-0.15 pCi/m³.

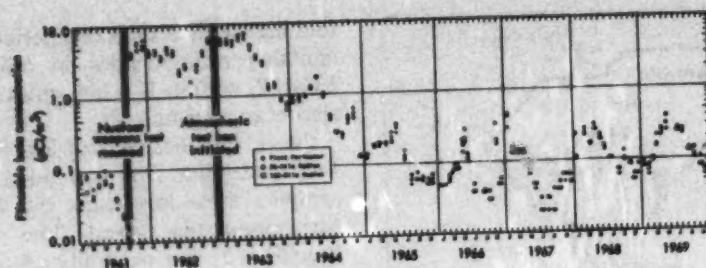


Figure 4. Influence of weapons tests

22 and 21 nCi/m² (excluding naturally occurring beryllium-7). Deposition at each sampling location is presented in table 6.

Water monitoring

The plant site is drained by five streams that flow several miles through the reservation before reaching the river (figure 5). In January 1965, the Beaufort-Jasper Water Authority began operation of a new treatment facility to furnish drinking water, partially supplied from the Savannah River, to most of Beaufort County, S.C. Water is supplied through a canal from the river at a location about 90 miles below the SRP. The city of Savannah also supplements its domestic well supply with river water during periods of peak de-

mand. The tritium concentrations in raw water collected from the Beaufort-Jasper Water Plant averaged 2 nCi/liter (0.07 percent of the AEC standard) during the July-December 1969 period. The annual radiation exposure of an individual in this population from the consumption of water containing this low concentration of tritium is 0.33 mrem. This exposure may be compared with 40 mrem/a from natural potassium found in the body of all persons or with the 170 mrem/a specified by the Federal Radiation Council as the annual dose guide for members of the public.

Communities near the plant get domestic water from deep wells or surface streams. Public water supplies from 14 surrounding towns were collected and analyzed in September. There was no evidence that SRP contributed radioactivity to

Table 6. Total fallout deposited, Savannah River Plant, July-December 1969

Sampling points	Radioactivity (nCi/m ²)						Beryllium-7 ^b
	Alpha ^a	Strontium-90	Strontium-90	Cesium-137	Cerium-141, -144	Zirconium-niobium-95	
Plant perimeter:							
A.....	2.4	0.9	0.3	0.8	1.1	2.8	5.7
B.....	2.0	1.1	.1	1.0	1.7	2.9	9.5
C.....	4.6	.8	.3	.8	1.7	2.7	10.2
D.....	2.5	.7	.2	.7	1.8	1.7	10.5
E.....	4.4	.8	.2	1.2	4.1	4.0	17.3
Average.....	3.2	.8	.2	.9	2.1	2.8	10.7
25-mile-radius:							
Aiken Airport.....	1.6	1.5	.3	1.1	3.6	4.1	14.1
Aiken State Park.....	1.3	1.0	.4	1.0	1.6	2.9	7.6
Allendale.....	2.3	.6	.3	.8	1.5	2.3	10.5
Barnwell.....	1.4	.8	.4	.9	3.4	5.4	10.7
Bush Field.....	2.0	.3	.3	.9	1.3	1.9	6.9
Langley.....	2.9	1.1	.4	1.2	3.2	4.3	14.8
Sardis.....	1.3	.8	.5	1.2	2.2	2.8	14.2
Waynesboro.....	2.1	.6	.2	1.9	1.3	3.7	9.0
Williston.....	1.6	.9	.3	1.0	2.0	4.4	8.7
Highway 301.....	3.9	1.0	.3	1.0	3.1	4.4	13.3
Average.....	1.9	.8	.3	1.0	2.3	3.7	11.0

^a Multiple by 10⁻³.

^b A naturally-occurring radionuclide. The beryllium-7 depositions reported for January-June 1969 are in error. The corrected range is 7.7-11.5 nCi/m².

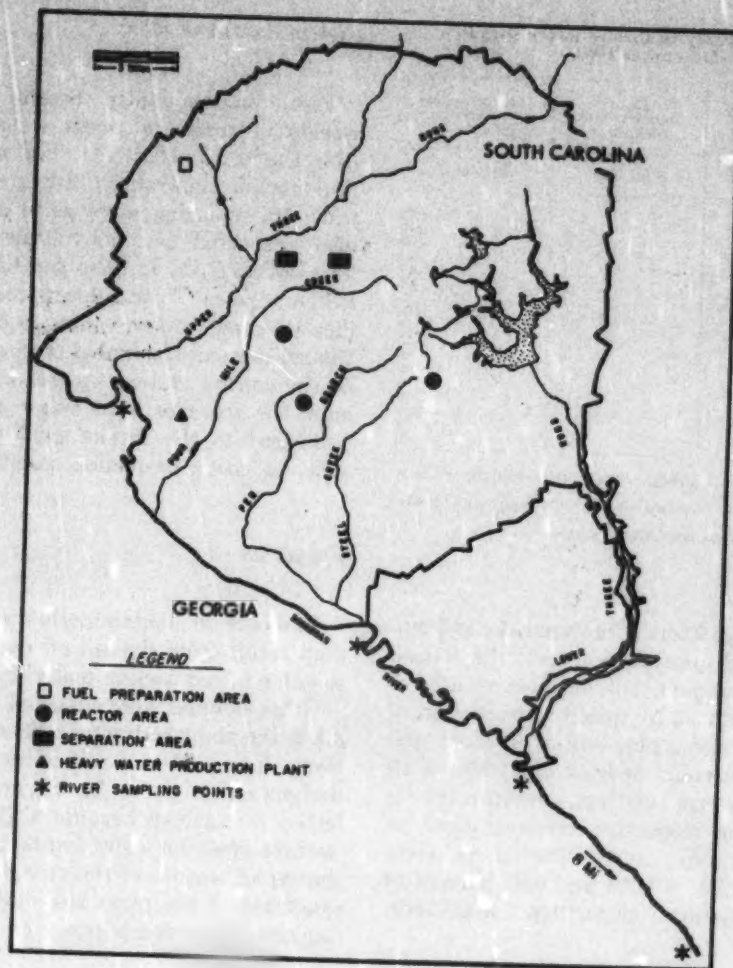


Figure 5. SRP production and effluent streams

drinking water supplies. Concentrations of alpha radioactivity (1.3 pCi/liter) and beta radioactivity (8 pCi/liter) were essentially the same as those observed before plant startup. Radioactivity in public water supplies data is presented in table 7.

River water, analyzed weekly, was sampled continuously at four locations, as shown in figure 5. Concentrations of alpha and nonvolatile beta radioactivity in river water for the past year are presented in table 3. Average concentrations of

specific radionuclides found in river water during July-December 1969 appear in table 9.

Tritium, sulfur-35, and trace amounts of cesium-137, strontium-89, and strontium-90 were the radionuclides of SRP origin detectable in river water at the downstream location. Strontium-90 and tritium from worldwide fallout were also detected in river water upstream from SRP effluents.

Tritium, a beta-particle emitter and the most abundant radionuclide released to the river, is produced by neutron irradiation of heavy-water

Table 7. Radioactivity in public water supplies, July-December 1969

Sampling points	Alpha radioactivity ^a (pCi/liter)	Nonvolatile beta radioactivity ^b (pCi/liter)
	September	September
Alben.....	1.4	4
Allendale.....	1.6	10
Augusta.....	ND	9
Barnwell.....	.4	ND
Beth.....	2.1	13
Blackville.....	.6	7
Clearwater.....	.3	4
Jackson.....	4.9	10
Langley.....	2.1	11
New Ellenton.....	2.5	11
North Augusta.....	.3	7
Sardis.....	ND	6
Waynesboro.....	.2	4
Williston.....	1.3	5
Average.....	1.3	8

^a AEC radiation protection standard—10 pCi/liter; sensitivity of analysis—0.2 pCi/liter.

^b AEC radiation protection standard—3 nCi/liter; sensitivity of analysis—4.0 pCi/liter.

ND, nondetectable, less than sensitivity of analysis.

moderator in the reactors. Chromium-51 and sulfur-35 (also a beta-particle emitter), the second and third most abundant radionuclides released to the river, are produced by neutron irradiation of stable chromium and stable sulfur. Tritium and chromium-51 are among the least dangerous of all radionuclides because neither concentrates in body tissues. The respective concentrations of tritium, chromium-51, and sulfur-35 in river water averaged 0.30, <0.001 and 0.01 percent of the AEC radiation protection standards, respectively.

Fish in Savannah River

Fish, predominantly bream, were collected weekly upstream, adjacent to, and downstream from the Savannah River Plant effluents. Specific radionuclide analyses of fish are summarized in table 10, replacing more generalized data previously reported as "nonvolatile beta activity." The radioactivity in bone and flesh from fish collected adjacent to and downstream from SRP indicates some minor contribution by SRP. Although measurably higher than similar collections at the control station upstream from SRP effluents, the increase is of minor significance when compared to the intake guides defined by the AEC radiation protection standards.

Vegetation

Radioactive contamination of growing plants may result from deposition on foliar surfaces or sorption of radioactive materials from the soil.

Grass samples were collected at seven locations along the plant perimeter and at seven other locations along a 25-mile radius route (these are not designated on figure 2). Bermuda grass was selected for analysis because of its importance as a pasture grass for dairy herds and its availability during all seasons of the year. Samples from each quadrant of the plant site and of the surrounding area were composited for monthly analysis

Table 8. Radioactivity in Savannah River water, July-December 1969

Sampling points	Alpha radioactivity ^a (pCi/liter)				Nonvolatile beta radioactivity ^b (pCi/liter)			
	July-December 1969			January-June 1969	July-December 1969			January-June 1969
	Maximum	Minimum	Average	Average	Maximum	Minimum	Average	Average
1 mile upstream from Upper Three Runs Creek (control).....	0.4	ND	ND	ND	10	ND	4	ND
Downstream from Steel Creek.....	.5	ND	ND	ND	14	ND	6	4
Downstream from Lower Three Runs Creek.....	.4	ND	ND	ND	23	ND	8	7
8 miles downstream from Lower Three Runs Creek.....	.2	ND	ND	ND	19	ND	7	5

^a AEC radiation protection standard—10 pCi/liter; sensitivity of analysis—0.2 pCi/liter.

^b AEC radiation protection standard—3 nCi/liter; sensitivity of analysis—4.0 pCi/liter.

ND, nondetectable, less than sensitivity of analysis.

Table 9. Average concentration of radionuclides in Savannah River water, July-December 1969

Nuclides	Concentration (pCi/liter)			
	Sensitivity of analysis	Control (1 mile upstream from Upper Three Runs Creek)	Highway 301 (8 miles downstream from Lower Three Runs Creek)	Percent AEC standard at Highway 301
Tritium	600	910	9,100	0.30
Ruthenium-103, 106	3.2	ND	ND	<.03
Cerium-141, 144	2.5	ND	ND	<.03
Cesium-134, 137	.6	ND	.8	<.004
Neptunium-239	2.2	ND	ND	<.003
Barium-lanthanum-140	1.6	ND	ND	<.01
Zirconium-niobium-95	.6	ND	ND	<.001
Chromium-51	4.3	ND	ND	<.001
Strontium-90	.3	ND	.4	.01
Iodine-131	.2	ND	.3	.10
Strontium-90	.01	.9	1.1	.37
Cobalt-60	1.4	ND	ND	<.005
Zinc-65	1.1	ND	ND	<.001
Manganese-54	.4	ND	ND	<.0004
Sulfur-35	5.0	ND	6.3	.01

ND, nondetectable, less than sensitivity of analysis.

Table 10. Radioactivity in Savannah River fish, July-December 1969

Location	Type of sample ^a	Concentration (pCi/g wet weight)			
		Strontium-90-90 ^b		Cesium-137	
		Maximum	Average	Maximum	Average
Above plant boundary (Control)	Bone	14	8	<2	<2
	Flesh	NA	NA	6	1
Adjacent to Plant	Bone	19	14	<2	<2
	Flesh	NA	NA	18	5
Below Plant at Highway 301	Bone	19	15	<2	<2
	Flesh	NA	NA	21	5

^a Monthly composites of weekly collections for strontium-90-90, and cesium-137.

^b Previous analyses have indicated a 1:100 strontium ratio between flesh and bone.

NA, no analysis.

Table 11. Radioactivity on vegetation, July-December 1969

Radionuclides ^a	Concentration (pCi/g dry weight)			
	Plant perimeter (7 locations)		25-mile radius (7 locations)	
	Maximum	Average	Maximum	Average
Alpha emitters	0.6	0.1	0.5	0.1
Cesium-137	3.5	1.1	1.3	.7
Cerium-141, 144	5.1	4.0	9.6	5.0
Ruthenium-103, 106	2.6	ND	3.8	ND
Beryllium-7	7.2	4.7	12.0	7.0
Iodine-131	ND	ND	ND	ND
Barium-lanthanum-140	ND	ND	ND	ND
Zirconium-niobium-95	3.4	2.2	5.8	2.6

^a Sensitivity of analysis in pCi/g dry weight, alpha emitters 0.10; cesium-137, 0.3; cerium-141, 144, 1.0; ruthenium-103, 106, 1.4; beryllium-7, 3.0; iodine-131, 0.2; barium-lanthanum-140, 0.0; zirconium-niobium-95, 0.5.

ND, nondetectable, less than sensitivity of analysis.

Milk

Gamma-emitting radionuclides in grass samples (excluding beryllium-7) were from fallout. Alpha-particle emitters averaged 0.1 pCi/g at the plant perimeter and 25-mile radius locations as compared to 0.2 pCi/g during the first half of 1969; gamma-ray emitters averaged 12.0 and 15.3 pCi/g, respectively, as compared to 17.6 and 22.4 pCi/g for the first half of 1969. Radioactivity in grass samples is presented in table 11. While the exact nature of the alpha radioactivity decrease is not known, the change is commensurate with previously observed changes that appear to be seasonal.

Milk was sampled at three dairies within a 25-mile radius of the Savannah River Plant (figure 2). Samples, collected biweekly, were analyzed for tritium and radioiodine. Strontium-90 and cesium-137 determinations were made quarterly. Milk produced in the area and sold by major distributors was also analyzed for these radionuclides. Results from analyzing milk for radioactivity during July-December 1969 are shown in table 12.

Average concentrations of the radionuclides in milk were 9 pCi/liter of strontium-90 (compared to 11 pCi/liter of strontium-90 during the first half of 1969) and 12 pCi/liter of cesium-137. Io-

Table 12. Radioactivity in milk from local dairies, Savannah River Plant, July-December 1969

Distributing points	Concentration						
	Tritium ^a (nCi/liter)			Strontium-90 ^b (pCi/liter)		Cesium-137 ^c (pCi/liter)	
	Maximum	Minimum	Average	September	December	September	December
Aiken.....	1	ND	ND	10	8	14	ND
North Augusta.....	4	ND	1.9	10	13	17	ND
Waynesboro.....	2	ND	1.3	NS	5	NS	10
Major distributors ^d	1	ND	1.0	9	8	10	8

^a Sensitivity of analysis—3 nCi/liter; AEC standard—3,000 nCi/liter.

^b Sensitivity of analysis—1.0 pCi/liter; AEC standard—300 pCi/liter.

^c Sensitivity of analysis—5.0 pCi/liter; AEC standard—300 pCi/liter.

^d Milk produced in local dairies, but sold by major distributors.

ND, nondetectable, less than sensitivity of analysis.

NS, no sample.

dine-131 was less than the sensitivity of the analysis (5 pCi/liter) throughout this period. These values are consistent with those reported by the U.S. Public Health Service for most sections of the United States. Tritium in local milk, when present, is assumed to be associated with plant operations. The average tritium level (1,300 pCi/liter) was 0.04 percent of the AEC standard for water.

Food

Samples of farm produce, representing four food categories (grain, fruit, poultry, and leafy vegetables), were collected at 14 localities in the six counties surrounding SRP (not shown on maps) during the summer and fall of 1969. Sixty samples were analyzed by gamma spectrometry for cerium-141-144, iodine-131, ruthenium-103-106, cesium-137, zirconium-niobium-95, and manganese-54. Radiochemical analyses were used for strontium-90 and alpha emitters (uranium and

plutonium). With the exception of grains, all foods were prepared for analysis in a manner similar to that used to prepare them for eating. Peelings, seeds, and other nonedible parts were removed. Wheat, containing the whole grains only, and oats, containing both grains and husks, were processed unwashed. Results are summarized in table 13. Concentrations in some samples were too low for reliable measurement, and only results above the detection limit of the analyses are included.

SRP contributions to the levels of radioactivity in foods were so low in 1969 as to be indistinguishable from fallout. With the exception of cesium-137 and strontium-90, all radionuclides in food were near or below levels of detection. Strontium-90 and cesium-137 were about the same as in the 1968 samples with respective peak averages again in collards (0.26 pCi/g) and grain (0.07 pCi/g).

Table 13. Radioactivity of agricultural products, Savannah River Plant, 1969

Products	Number of samples	Concentration ^a (pCi/g net weight)									
		Strontium-90		Cerium-141, 144		Zirconium-niobium-95		Cesium-137		Alpha emitters	
		Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Collards.....	14	0.26	0.43	0.12	0.20	ND	ND	0.05	0.11	0.002	0.008
Plums.....	14	.04	.14	ND	.33	ND	ND	ND	.04	.002	.011
Oats, rye, wheat.....	14	.15	.25	.11	.19	.06	.19	.07	.10	.003	.024
Corn.....	14	.03	.09	ND	ND	ND	ND	.06	.15	ND	.004
Chicken.....	6	.09	.14	ND	ND	ND	ND	.06	.07	.002	.012

^a Sensitivity of analysis in pCi/g, wet weight; strontium-90, 0.02; cerium-141, 144, 0.06; zirconium-niobium-95, 0.02; cesium-137, 0.02; alpha emitters, 0.002.

Environmental gamma radiation levels

Monthly measurements of environmental gamma radiation were made with thermoluminescent dosimeters. The July-December 1969 data (shown in table 14) are characteristic of measurements observed at individual stations for the past several years.

Table 14. Environmental gamma radiation, Savannah River Plant, July-December 1969

Sampling points	Gamma radiation (mR/24 h)		
	Maximum	Minimum	Average
Plant perimeter:			
A.....	0.57	0.09	0.24
B.....	.40	.09	.30
C.....	.42	.09	.23
D.....	.43	.07	.16
E.....	.23	.07	.14
Average.....			0.19
25-mile-radius:			
Aiken Airport.....	.28	.07	.16
Aiken State Park.....	.28	.03	.15
Allendale.....	.46	.03	.23
Barwell.....	.24	.07	.17
Duck Field.....	.33	.12	.22
Langley.....	.30	.07	.19
Sardis.....	.30	.07	.18
Waynesboro.....	.24	.05	.15
Williston.....	.38	.19	.19
Highway 301.....	.48	.09	.31
Average.....			0.20

Summary

The quantity of radioactive waste released by the Savannah River Plant to its environs was, for the most part, too small to be distinguished from natural background radiation or was obscured by fallout from offsite sources. Beta radioactivity in air, which showed no relationship with plant operations, was about the same as that observed for January-June 1969 and was a twofold increase over the same period of 1968. Radioactive materials in fish flesh continued to be far below levels considered significant from a health standpoint. The average concentration of any radionuclide in river water at Highway 301 did not exceed 0.4 percent of the AEC radiation protection standard.

Recent coverage in Radiological Health Data and Reports:

Period	Issue
July-December 1968	November 1969
January-June 1969	May 1970

3. S1C Prototype Reactor Facility⁴ January-December 1969

Combustion Engineering, Inc.
Windsor, Conn.

The S1C Prototype Reactor Facility is a land-based nuclear submarine power plant operated for the Atomic Energy Commission by the Naval Reactors Division of Combustion Engineering, Inc. (figure 6). The prototype contains a pressurized water reactor power plant which is primarily used to train personnel in the operation of naval reactor power plants. Reactor power operations at the S1C Prototype Facility began in December 1959.

⁴ Summarized from "S1C Prototype Reactor Facility Environmental Monitoring, Report for 1969."

December 1970

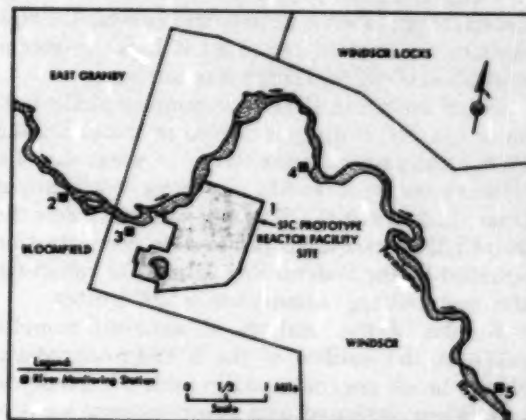


Figure 6. Environmental monitoring locations S1C Prototype site

The low-level radioactive waste discharged intermittently from S1C prototype operations consists mainly of water. Small quantities of airborne particulates in gaseous waste are also generated

and released on occasion in the ventilation exhaust air.

Essentially, all of the radioactive waste originates from the activation of minute amounts of impurities or corrosion products in the circulating water used as a reactor coolant. All materials released to the environment are routinely monitored to assure that waste disposal operations comply with AEC regulations.

Liquid radioactive waste

Drainage from all systems which are known to contain radioactive liquids were collected, processed and sampled prior to discharge to the environment to assure that discharge concentrations were within the required limits. In addition, waste effluent is sampled as it is discharged to the environment. These samples are analyzed for radioactivity, and the results are retained as part of the permanent records.

The S1C Prototype discharged a total of 1.84 megaliters of radioactive liquid waste containing 285.2 microcuries of radioactivity during 1969 for an annual average discharge concentration of 150 pCi/liter.

Water monitoring

Water and sediment samples from the Farmington River are taken quarterly and analyzed. These samples are used to determine if buildup (reconcentration of radioactivity) is occurring.

The Farmington River was sampled at the outlet of the S1C Prototype discharge brook. During 1969, gross gamma radioactivity of water samples from the outlet of the S1C discharge brook ranged from ≤ 5.9 to 410 pCi/liter which is well below the 30 nCi/liter maximum permissible concentration specified by the Federal Regulations for cobalt-60, the most limiting radionuclide in S1C wastes.

Results of the analysis of sediment samples taken at the outflow of the S1C Prototype discharge brook are contained in table 15. These results when compared with preoperational surveys indicate that no significant buildup of radioactivity has occurred.

Airborne radioactivity

All areas onsite where gaseous and/or particulate airborne radioactivity could be present are

Table 15. Farmington River sediment sample results, 1969

Period (1969)	Average gross gamma concentration at outlet of discharge brook (pCi/g)
January-March	(*)
April-June	0.46
July-September	1.68
October-December	3.1

* Sample not taken because of ice on river.

directed through ducts to monitored stacks. The stacks are monitored for airborne levels on a continuous basis. The facility's operational controls ensure that the radioactive concentration in the environment does not exceed the 100 pCi/m³ limit. This limit is based on levels of strontium-90 and alpha-particle emitting isotopes being insignificant.

The airborne particulate radioactivity samples taken during discharge are recounted 4 hours after discharge. This delay allows short-lived radioactivity to decay. The air effluent analysis records indicate that no significant airborne radioactivity was discharged above natural backgrounds levels.

Radiation evaluation

Film badges were posted on the site's exclusion area perimeter for the detection of beta-gamma radiation. The badges were processed monthly, and the exposure results were generally less than 10 millirem. The normal background for the surrounding area not influenced by S1C Prototype operation is also 10 millirem per month.

Conclusions

Results of the analyses and of the continuous monitoring throughout 1969 have indicated that S1C Prototype operations have met all of the Federal Regulations pertaining to AEC standards. Environmental analyses indicate that no significant quantities of radioactivity have accumulated above the preoperational environmental results. It is, therefore, concluded that the facility operations have not adversely affected the surrounding environment.

Recent coverage in Radiological Health Data and Reports:

Period	Issue
January-December 1968	July 1970

Radiological Health Data and Reports

Reported Nuclear Detonations, November 1970

(Includes seismic signals from foreign test areas)

On November 4, 1970, the United States recorded seismic signals which presumably originated from the Soviet underground nuclear test area in the Semipalatinsk region. The signals were equivalent to those of nuclear test in the low-intermediate yield range of 20-200 kilotons TNT.

The U.S. Atomic Energy Commission announced only one test for November 1970. A nuclear test of low-intermediate yield (equivalent to 20-200 kilotons TNT) was conducted underground at the Nevada Test Site on November 5, 1970.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U. S. nuclear detonations may be obtained upon request from the Division of Public Information, U. S. Atomic Energy Commission, Washington, D. C. 20545.

1997

228

NUCLEAR POWER PLANTS IN THE UNITED STATES

The nuclear power plants included in this map are ones whose power is being transmitted or is scheduled to be transmitted over utility electric power grids and for which reactor suppliers have been selected

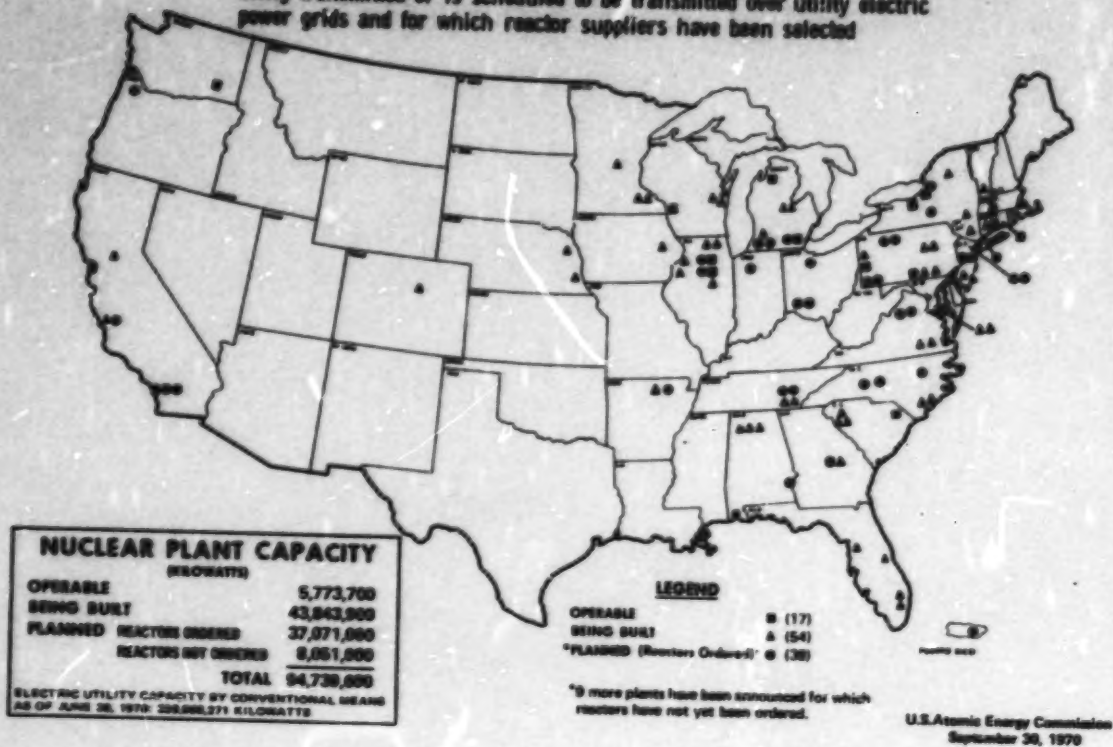


Figure 1. Nuclear power plants in the United States—continued

Annual Subject Index

Radiological Health Data and Reports

Volume 11—1970

A

- A decade of publication, *Mar:107*
 Air—see also atmospheric contaminants
 Radiation Alert Network
 Strontium and plutonium isotopes in ground level air,
 October 1963–March 1969, *Mar:129*
 Alaska
 Cesium-137 concentrations in Eakimos, spring 1968,
May:219
 Radionuclide analysis of Coast Guard water supplies,
 January 1968–July 1969, *Feb:83*
 Radionuclides in Alaskan caribou and reindeer, May–
 December 1969, *Oct:563*
 Analysis of iodine-131 in bovine thyroids, October 1964
 through February 1969, *Nov:573*
 An investigation of x radiation from color television receivers
 in Suffolk County, New York, *Apr:179*
 A priority system for the inspection of x-ray facilities,
Aug:367
 Argonne National Laboratory
 July–December 1968, *Feb:95*
 January–June 1969, *July:357*
 Arizona
 Environmental survey of uranium tailings pile Monu-
 ment Valley, Ariz., *Oct:511*
 Atmospheric contaminants
 Environmental levels of radioactivity in Utah following
 Operation Pinetripe, *Feb:65*
 Environmental surveillance around nuclear power re-
 actors, *July:325*
 Environmental survey of uranium tailings pile, Monu-
 ment Valley, Ariz., *Oct:511*
 Krypton-85 levels in the environment determined from
 dated krypton gas samples, *Dec:571*
 Offsite surveillance around the Nevada Test Site, July–
 December 1965, *Mar:165*
 Plutonium in airborne particulates and precipitation
 July–September 1968, *Feb:92*
 January–March 1969, *Aug:410*
 Some measurements on radioactivity in Sweden caused
 by nuclear test explosions, *Oct:487*
 Surface Air Sampling Program—80th Meridian Network,
 January–December 1966, *Oct:554*
 Zirconium-95 in Utah vegetation produced during the
 1966 growing season, *June:277* errata, *Oct: 572*
 Atmospheric levels of radioactivity—see atmospheric con-
 taminants; environmental levels of radioactivity at
 Atomic Energy Commission installations; fallout; nu-
 clear tests; reported nuclear detonations
 Atomic Energy Commission installations—see Argonne;
 Atomics International; Bettis; Feed Materials Production
 Center; Knolls; Lawrence; Los Alamos; Mound; National;
 Neutron Devices; Oak Ridge; Paducah; Portsmouth;
 Rocky Flats; Savannah; Shippingport; SIC Prototype
 Atomics International
 Jan–June 1969, *Mar:172*
 July–Dec 1969, *Aug:172*

B

- Barium-lanthanum-140—see atmospheric contaminants;
 Atomic Energy Commission installations; fallout; milk
 Bettis Atomic Power Laboratory
 Jan–Dec 1968, *Jan:37*
 Jan–Dec 1969, *Sept:476*
 Body burdens
 Tritium body burden of children, 1967–1968, *May:227*
 Bone
 Strontium-90 in human bone
 Jan–Mar 1969, *Mar:169*
 Apr–June 1969, *May:361*
 July–Sept 1969, *June:316*
 Oct–Dec 1969, *Sept:473*
 Strontium-90 in human bones in the United States,
 1962–1966, *Apr:183*
 Bovine thyroids
 Analysis of iodine-131 in bovine thyroids, October 1964
 through February 1969, *Nov:573*
 Iodine-131 in bovine thyroids, summary of program
 operations, 1963–1969, *June:313*

C

- Calcium—see diet; milk
 California
 Estimated daily intake of radionuclides in California
 diets, Oct–Dec 1968, and Jan–Mar 1969, *May:248*
 Apr–Dec 1969 and Jan–June 1970, *Nov:628*
 Radioactivity in California waters, July–December 1968,
Aug:400
 Canada
 Canadian air and precipitation monitoring program
 Sept 1969, *Jan:33* Mar 1970, *July:353*
 Oct 1969, *Feb:89* Apr 1970, *Aug:407*
 Nov 1969, *Mar:161* May 1970, *Sept:471*
 Dec 1969, *Apr:203* June 1970, *Oct:549*
 Jan 1970, *May:257* July 1970, *Nov:645*
 Feb 1970, *June:309* Aug 1970, *Dec:699*
 Caribou
 Radionuclides in Alaskan caribou and reindeer, May–
 December 1969, *Oct:563*
 Cesium-137—see also diet; milk
 Cesium-137 concentrations in Eakimos, Spring 1968,
May:219
 Elevated levels of cesium-137 in common mushrooms
 (Agaricaceae) with possible relationship to high levels
 of cesium-137 in whitetail deer, 1968–1969, *Oct:527*
 Radioactive cesium in estuaries, *Dec:659*
 Strontium-90 and cesium-137 in total diet samples—a
 comparative study of data, *Feb:47*
 Coast Guard
 Radionuclide analysis of Coast Guard water supplies,
 January 1968–July 1969, *Feb:83*
 Color television
 An investigation of x radiation from color television re-
 ceivers in Suffolk County, New York, *Apr:179*

- Results of a study of color television set assembly and repair workers x-ray safety, Oct:519
 Connecticut
 Estimated daily intake of radionuclides in Connecticut standard diet,
 July-December 1968 and January-June 1969, Feb:80
 July-December 1969, Dec:684

D

- Dental x rays
 Diagnostic dental x rays and the patient—an overview, Jan:1
 Results of a program directed toward reduction of dental x-ray exposure, Mar:109
 Results of 33,911 x-ray protection surveys of facilities with medical or dental diagnostic x-ray equipment, fiscal years 1961-1968, Nov:581
 Detonations—see nuclear detonations
 Diet
 Estimated daily intake of radionuclides in diet—see California, Connecticut
 Radionuclides in Institutional diet samples
 Apr-June 1969, Jan:22
 July-Sept 1969, June:294
 Oct-Dec 1969 and annual summary 1969, Aug:394
 Jan-Mar 1970, Nov:633
 Strontium-90 and cesium-137 in total diet samples—a comparative study of data, Feb:47
 Strontium-90 in Tri-City diets
 Jan-Dec 1969, June:297
 Disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities, 1969, Aug:373
 errata, Oct: 572

E

- Elevated levels of cesium-137 in common mushrooms (*Agaricaceae*) with possible relationship to high levels of cesium-137 in whitetail deer, 1968-1969, Oct:527
 Environment
 Krypton-85 levels in the environment determined from dated krypton gas samples, Dec:671
 Environmental levels of radioactivity at Atomic Energy Installations—see Argonne; Atomica International; Bettis; Feed Materials Production Center; Knolls; Lawrence; Los Alamos; Mound; National; Neutron Devices; Oak Ridge; Paducah; Portsmouth; Rocky Flats; Savannah; Shippingport; S1C Prototype
 Environmental levels of radioactivity in Utah following Operation Pinstripe, Feb:55
 Environmental surveillance around nuclear power reactors, July:325
 Environmental survey of uranium tailings pile, Monument Valley, Ariz., Oct:511
 Natural environmental radioactivity in south Florida sands and soils, February-June 1968, Sept:441
 Errata,
 Evaluation of emissions from radium dial watches, Jan:7
 Exposures—see also x ray
 Lead content of glass used for shielding television receiver components and its relation to exposure rate, Mar:135
 Results of a program directed toward reduction of dental x-ray exposure, Mar:109

F

- Fallout—see atmospheric contaminants; environment

- Feed Materials Production Center
 Jan-June 1969, Mar:175
 July-Dec 1969, Aug:415
 Florida
 Elevated levels of cesium-137 in common mushrooms (*Agaricaceae*) with possible relationship to high levels of cesium-137 in whitetail deer, 1968-1969, Oct:527
 Natural environmental radioactivity in south Florida sands and soils, February-June 1968, Sept:441
 Radioactivity in Florida waters, 1968, Mar:154
 Fluoroscopy—see x ray
 Food—see also diet; milk
 Tritium concentrations in food, 1967-1968, May:233

G

- Gamma activity—see atmospheric contaminants

H

- Healing arts—see also x ray
 Survey results of the use of x rays in the healing arts specialties in North Dakota, 1964-1968, Mar:117
 Human bone
 Strontium-90 in human bone,
 Jan-Mar 1969, Mar:169
 Apr-June 1969, May:261
 July-Sept 1969, June:316
 Oct-Dec 1969, Sept:473
 Strontium-90 in human bones in the United States, 1962-1966, Apr:183

I

- Interstate carrier drinking water analysis program, 1967-1969, Dec:688
 Iodine-131
 Analysis of iodine-131 in bovine thyroids, October 1964 through February 1969, Nov:573
 Iodine-131 in bovine thyroids, summary of program operations, 1963-1969, June:313

J, K, L

- Kansas
 Kansas milk network, January-December 1969, Sept:459
 Preliminary survey of x-ray producing devices in Kansas schools, 1968, Nov:613
 Radioactivity in Kansas surface waters, January-December 1969, Sept:464
 Knolls Atomic Power Laboratory
 Jan-Dec 1968, Oct:565
 Krypton-85
 Krypton-85 levels in the environment determined from dated krypton gas samples, Dec:671
 Lead content of glass used for shielding television receiver components and its relation to exposure rates, Mar:135
 Lawrence Radiation Laboratory
 Jan-June 1969, Apr:207
 July-Dec 1969, Nov:649
 Los Alamos Scientific Laboratory
 Jan-Dec 1969, Sept:478

M

Maryland

Radioactive cesium in estuaries, Dec:859

Mexican Air Monitoring Program

Mar-April 1969, Jan:34

May-June 1969, Feb:90

July-Aug 1969, Mar:163

Sept-Oct 1969, Apr:204

Nov 1969, May:253

Dec 1969, Aug:408

Jan-June 1970, Oct:580

July 1970, Nov:646

Microwave

Nassau County microwave oven study, July 1970,

Dec:667

Milk

Kansas milk network, January-December 1969, Sept:459

Milk surveillance

Sept 1969, Jan:11

Oct 1969, Feb:69

Nov 1969, Mar:141

Dec 1969, Apr:187

Jan 1970, May:227

Feb 1970, June:223

Standby milk surveillance network, Aug:379

Minnesota

Radioactivity in Minnesota municipal water supplies,

January-June 1969, Jan:96

Mound Laboratory

Jan-June 1969, June:319

July-Dec 1969, Dec:701

N

Nassau County microwave oven study, July 1970, Dec:667

National Reactor Testing Station

July-Dec 1968, June:321

Natural environmental radioactivity in south Florida

sands and soils, February-June 1968, Sept:441

Neutron Devices Department

July-Dec 1968, Jan:39

Jan-June 1969, Apr:212

July-Dec 1969, Aug:417

Nevada

Offsite surveillance around the Nevada test site, July-

December 1968, Mar:165

New York

An investigation of x radiation from color television re-

ceivers in Suffolk County, New York, Apr:179

Nassau County microwave oven study, July 1970,

Dec:667

Radioactivity in New York surface water, January-

June 1969, June:302

North Dakota

Survey results of the use of x rays in the healing arts

specialties in North Dakota, 1964-1968, Mar:117

Nuclear detonations

Reported nuclear detonations (includes seismic signals

from foreign test areas)

Dec 1969, Jan:45

Jan 1970, Feb:105

Feb 1970, Mar:177

Mar 1970, Apr:217

Apr 1970, May:275

May 1970, June:324

June 1970, July:366

July 1970, Aug:419

Aug 1970, Sept:483

Sept 1970, Oct:571

Oct 1970, Nov:658

Nov 1970, Dec:715

Nuclear power

Environmental surveillance around nuclear power re-

actors, July:555

Nuclear power plants in the United States, Sept:484;

Dec:714

Nuclear powered ships

Disposal of radioactive wastes from U.S. Naval nuclear-

powered ships and their support facilities, 1969, Aug:373

Nuclear tests

Environmental levels of radioactivity in Utah following

Operation Pinetree, Feb:65

Some measurements on radioactivity in Sweden caused by

nuclear test explosions, Oct:487

O

Oak Ridge Area

July-Dec 1968, Jan:41

Jan-June 1969, May:264

Offsite surveillance around the nuclear test site, July-

December 1968, Mar:165

Operation Pinetree

Environmental levels of radioactivity in Utah following

Operation Pinetree, Feb:65

P, Q

Paducah Plant

Jan-June 1969, Apr:219

July-Dec 1969, Sept:479

Pan American Health Organization

Pan American Air Sampling Program

Sept 1969, Jan:35

Oct 1969, Feb:91

Nov 1969, Mar:163

Dec 1969, Apr:205

Jan 1970, May:259

Feb 1970, June:310

Mar 1970, July:354

Apr 1970, Aug:409

May 1970, Sept:478

June 1970, Oct:553

July 1970, Nov:647

Aug 1970, Dec:700

Pan American Milk Sampling Program, see milk surveillance

Particulates—see atmospheric contaminants; atmospheric

levels of radioactivity; Atomic Energy Commission in-

stallations; Radiation Alert Network

Pasteurized Milk Network, see milk surveillance

Plutonium

Plutonium in airborne particulates and precipitation

July-Sept 1968, Feb:92

July-Dec 1968, June:311

Plutonium in airborne particulates

Jan-Mar 1969, Aug:410

Apr-Dec 1969, Oct:552

Strontium and plutonium isotopes in ground level air,

October 1969-March 1969, Mar:129

Portsmouth Area Gaseous Diffusion Plant

Jan-June 1969, Apr:216

July-Dec 1969, Oct:569

Precipitation—see also atmospheric contaminants; atmce-

pheric levels of radioactivity; Radiation Alert Network

Tritium concentration in precipitation

1967-1968, Mar:137

Tritium in precipitation

Jan-June 1969, June:310

July-Dec 1969, July:354

Preliminary survey of x-ray producing devices in Kansas

schools, 1968, Nov:613

Priority system for the inspection of x-ray facilities, Aug:367

R

Radiation Alert Network

Sept 1969, Jan:30

Oct 1969, Feb:86

Nov 1969, Mar:158

Dec 1969, Apr:200

Jan 1970, May:254

Feb 1970, June:306

Mar 1970, July:350

Apr 1970, Aug:404

May 1970, Sept:468

June 1970, Oct:516

July 1970, Nov:642

Aug 1970, Dec:696

Radioactive cesium in estuaries, Dec:559

Radioactivity

Radioactivity in air,orne particulates and precipitation—see Canada; Mexican; Pan American Health Organization; plutonium; Radiation Alert Network; Surface Air Sampling Network

Environmental levels of radioactivity in Utah following Operation Pinstripes, Feb:55

Natural environmental radioactivity in south Florida sands and soils, February–June 1968, Sept:441

Radioactivity in California waters, July–December 1968, Aug:400

Radioactivity in Florida waters, 1968, Mar:154

Radioactivity in Kansas surface waters, January–December 1969, Sept:464

Radioactivity in Minnesota municipal water supplies, January–June 1969, Jan:36

Radioactivity in New York surface water, January–June 1969, June:308

Some measurements on radioactivity in Sweden caused by nuclear test explosions, Oct:487

Radionuclide analysis of Coast Guard water supplies, January 1968–July 1969, Feb:33

Radionuclides in Alaskan caribou and reindeer, May–December 1969, Oct:563

Radionuclides in institutional diet samples, see diet

Radiostrontium

Radiostrontium in tap water, Jan–Dec 1969, July:348

Radium—see also diet

Evaluation of emissions from radium dial watches, Jan:7

Raw milk—see milk surveillance

Reactors—see also Atomic Energy Commission

Environmental surveillance around nuclear power reactors, July:225

Nuclear power plants in the United States, Sept:484; Dec:714

Reindeer—see Alaska

Reported nuclear detonations—see nuclear detonations

Results of a program directed toward reduction of dental x-ray exposure, Mar:109

Results of a study of color television set assembly and repair workers x-ray safety, Oct:519

Results of 33,911 x-ray protection surveys of facilities with medical or dental diagnostic x-ray equipment, fiscal years 1961–1968, Nov:581

Rocky Flats Plant

Jan–June 1969, Feb:100

S

S1C Prototype Reactor Facility

Jan–Dec 1968, July:364

Jan–Dec 1969, Dec:711

Savannah River Plant

Jan–June 1969, May:368

July–Dec 1969, Dec:704

Shippingport Atomic Power Station

Jan–Dec 1969, Nov:555

Some measurements on radioactivity in Sweden caused by nuclear test explosions, Oct:487

Standby milk surveillance network, Aug:379

State milk surveillance activities—see milk

Strontium-89—see diet; milk; water

Strontium-90—see also Alaska; atmospheric contaminants; bone; diet; environmental levels at AEC installations; milk; water

Strontium-90 and cesium-137 in total diet samples—a comparative study of data, Feb:47

Strontium-90 in human bone

Jan–Mar 1969, Mar:169

Apr–June 1969, May:361

July–Sept 1969, June:316

Oct–Dec 1969, Sept:473

Strontium-90 in human bones in the United States, 1962–1968, Apr:183

Strontium and plutonium isotopes in ground level air, October 1963–March 1969, Mar:129

Strontium-90 in tri-city diets, January–December 1969, June:337

Standby milk surveillance network, Aug:379

Surface air sampling program—80th meridian, January–December 1964, Oct:554

Surface waters—see water

Survey results of the use of x rays in the healing arts specialties in North Dakota, 1964–1968, Mar:117

T

Television

An investigation of x radiation from color television receivers in Suffolk County, New York, Apr:179

Lead content of glass used for shielding television receiver components and its relation to exposure rate, Mar:135

Results of a study of color television set assembly and repair workers x-ray safety, Oct:519

Thyroid

Analysis of iodine-131 in bovine thyroids, October 1964 through February 1969, Nov:573

Iodine-131 in bovine thyroids, summary of program operations, 1963–1969, June:313

Tri-city diet study

Strontium-90 in tri-city diets, January–December 1969, June:337

Tritium

Tritium body burden of children, 1967–1968, May:227

Tritium in community water supplies, 1969, Dec:592

Tritium concentration in precipitation, 1967–1968, Mar:137

Tritium concentrations in food, 1967–1968, May:233

Tritium in precipitation

Jan–June 1969, June:310

July–Dec 1969, July:354

Tritium in streams in the United States, 1961–1968, Sept:421

Tritium in surface water network

July–Dec 1969, July:347

Jan–June 1970, Nov:538

U, V

Uranium

Environmental survey of uranium mill tailings pile, Monument Valley, Ariz., Oct:511

Utah

Environmental levels of radioactivity in Utah following

Operation Pinstripes, Feb:55

Zirconium-95 in Utah vegetation produced during the 1966 growing season, June:377 errata, Oct: 572

W

Wastes

Disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities, 1969, Aug:373

errata, Oct: 572

Water—see also Alaska; Atomic Energy Commission installations

Interstate carrier drinking water analysis program, 1967–1969, Dec:588

Radioactivity in California waters, July–December 1968, Aug:400

Radioactivity in Kansas surface waters, January-December 1969, *Sept:161*
 Radioactivity in Minnesota municipal water supplies, January-June 1969, *Jan:96*
 Radioactivity in New York surface water, January-June 1969, *Jan:908*
 Radiocesium analysis of Coast Guard water supplies, January 1968-July 1969, *Feb:23*
 Radiostrontium in tap water, January-December 1969, *July:216*
 Tritium in community water supplies, 1969, *Dec:598*
 Tritium in streams in the United States, 1961-1968, *Sept:181*
 Tritium in surface water network
 July-Dec 1969, *July:217*
 Jan-June 1970, *Nov:638*

X, Y, Z

X Ray

An investigation of x radiation from color television receivers in Suffolk County, New York, *Apr:179*

A priority system for the inspection of x-ray facilities, *Aug:367*
 Diagnostic dental x rays and the patient—an overview, *Jan:1*
 Preliminary survey of x-ray producing devices in Kansas schools, 1968, *Nov:613*
 Results of 33,911 x-ray protection surveys of facilities with medical or dental diagnostic x-ray equipment, fiscal years 1961-1968, *Nov:581*
 Results of a program directed toward reduction of dental x-ray exposure, *Mar:109*
 Results of a study of color television set assembly and repair workers x-ray safety, *Oct:519*
 Survey results of the use of x rays in the healing arts specialties in North Dakota, 1964-1968, *Mar:117*
 Zirconium-95
 Zirconium-95 in Utah vegetation produced during the 1966 growing season, *June:577* errata, *Oct: 578*

Author Index

Radiological Health Data and Reports

Volume 11—1970

Alcox, R. W.	Nov:581	Malcolm, J. C.	Mar:109
Baratta, E. J.	Apr:183	Mangano, J. J.	Aug:373
Becker, S.	Apr:179	McDowell, R. B.	Nov:581
Bernstein, S. V.	Dec:667	Mikkelsen, R. L.	May:219
Christianson, G. A.	Mar:117	Miles, M. E.	Aug:373
Cochran, J. A.	Mar:129	Miller, C. E.	Dec:667
Coogan, J. S.	May:219	Moghissi, A. A.	Mar:137; May:227-233; Dec:671
Dauer, M.	Sept:441	Nayfield, C. L.	Oct:527
Dillard, B. L.	Aug:367	Pendleton, R. C.	Feb:65; June:277
Eckert, J. A.	May:219	Phillips, C. R.	Dec:671
Farnsworth, R. K.	Sept:421	Pliner, G. A.	Nov:573
Ferri, E. S.	Apr:183	Porter, C. R.	Mar:137
Fenn, L. R.	Nov:581	Riel, G. K.	Dec:659
Gragg, R. L.	Jan:7	Robinson, E. W.	Jan:7
Hardin, C. M.	Aug:367	Roecklein, P. D.	Feb:47
Harward, E. D.	July:325	Rolofson, J. W.	Jan:7
Jameson, W. R.	Nov:581	Rosenthal, R. B.	Mar:109
Johnson, W.	Oct:527	Ruggers, P. S.	Mar:135
Keefer, D. H.	Sept:441	Russell, J. L.	Nov:573
Klein, H. F.	Jan:7	Savic, S. D.	Oct:519
Kraeger, J. A.	Mar:117	Sharpe, T. J.	Aug:379
Lem, P. N.	May:219	Shleien, B.	Mar:129
Levine, H.	Mar:135	Shuping, R. E.	Dec:671
Lieberman, J. A.	July:325	Simpson, R. E.	Feb:47
Lieberman, R.	May:227	Smedley, C. E.	Feb:47
Lloyd, R. D.	Feb:65 June:277	Snellings, R. N.	Oct:511
Lyon, R. J.	May:233	Snihs, J. O.	Oct:487
Mafrici, D.	Dec:667	Spencer, Jr., L. W.	Nov:613
Magi, A.	Oct:487	Stein, J. L.	Aug:379
Magno, P. J.	Mar:129	Steward, G. L.	Sept:421
		Swedjemark, G. A.	Oct:487
		Wall, M. A.	Apr:133
		Weaver, C. L.	July:325
		Wyerman, T. A.	Sept:421

SYNOPSIS

Synopsis of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

RADIOACTIVE CESIUM IN ESTUARIES. Gordon K. Riel. *Radiological Health Data and Reports*, Vol. 11, December 1970, pp. 659-663.

The concentration of dissolved cesium-137 from fallout in the Chesapeake Bay is on the order of 0.3 pCi/liter, while the concentration is less than 0.1 pCi/liter in the rivers and ocean that supply the bay's water. The ratio of radio-cesium concentration to salinity in the bay is fairly independent of location and season. Brief studies elsewhere indicate that this pattern is typical of estuaries.

KEYWORDS: Cesium-137, Chesapeake Bay, estuaries, salinity, water

NASSAU COUNTY MICROWAVE OVEN STUDY, JUNE 1969-March 1970. David Mafrit, Sheldon V. Bernstein, and Charles E. Miller. *Radiological Health Data and Reports*, Vol. 11, December 1970, pp. 667-670.

The Radiological Health Section of the Nassau County Department of Health conducted a survey of microwave ovens located in Nassau County, New York. A total of 166 ovens were surveyed between June 1969 and March 1970. It was found that 23 of the 166 ovens (14 percent) exceeded the industry's standard of 10 mW/cm² during normal operation. When the door was in the process of being opened, 69 of the 166 ovens (42 percent) exceeded the standard. The owners and the manufacturers of the ovens were notified of the results of the survey and recommendations were made for correction of deficiencies.

KEYWORDS: Interlock system, microwave leakage, microwave ovens, New York, radiation, survey

KRYPTON-85 LEVELS IN THE ENVIRONMENT DETERMINED FROM DATED KRYPTON GAS SAMPLES. R. E. Shuping, C. R. Phillips, and A. A. Moghissi. *Radiological Health Data and Reports*, Vol. 11, December 1970, pp. 671-672.

A program to monitor the krypton-85 atmospheric concentrations in the United States is described, and concentrations of krypton-85 at several sites are presented. A brief description of the analytical method is given and values obtained are compared with those reported or predicted by others.

KEYWORDS: atmosphere, environmental monitoring, krypton-85, liquid scintillation, United States